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THE PHYSIOGRAPHY OF SOUTHWESTERN ONTARIO

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This is the third article dealing with the surface features of southern Ontario. The first two covered the central and eastern sections leaving the peninsular part, up to and including the Niagara Escarpment, to be described at this time. This area measures 225 miles from east to west along Lake Erie and averages 135 miles from Lake Erie to Georgian Bay, while the Bruce Peninsula projects 60 miles further to the northwest. It is one of the best farming districts of Canada, comprising 95,000 farms (10 million acres), and has one and one-quarter million inhabitants. For an area of its size it has a wide range of climate; the lowlands bordering the Great Lakes have longer summers and less rainfall than the higher hinterland. Since it is a glaciated region the soils are young and variable; the variations resulting mainly from differences in topography, depth to bedrock, manner of deposition and the nature of the surface drift. This account of the physiography of Southwestern Ontario discusses those differences. It is based on three summers field work and available geological information. In addition to its contribution to an understanding of the soils it is hoped that it will stimulate an appreciation of the landscape.

BEDROCK

The build of the region is due to the bedrock. This in turn governed the movement of the glaciers; that is, they advanced through the lowlands or flowed around the uplands, and the distribution of the glacial deposits followed. Glacial till invariably contains some foreign rock imported by the glacier. However, it is usual to find that a high proportion of the material comes from the underlying formations. The names of the various local rocks will be mentioned throughout this report, so that for these reasons it is well to discuss bedrock at the outset.

Figure 3 was copied from maps of the Geological Survey of Canada and shows the distribution of the several formations. The oldest strata appear along the eastern border and these are overlapped by younger layers of dolomite, shale, sandstone or limestone. The sandstone beds are thin and this rock does not appear extensively at the surface. The shale is in three bands of which the Queenston and Medina are the most notable and the Salina the least prominent. The Queenston shale is mostly red in colour and easily identified even if broken into small pieces or ground to a

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powder. The Salina (salt-bearing) formation contains green, grey and a little red shale interbedded with limestone and dolomite. The Huron shale is black and calcareous, and the Hamilton formation includes shale interbedded with limestone. The Lockport and Guelph dolomites occupy a belt immediately west of the Niagara Escarpment. The Onondaga and Delaware limestones of the Norfolk formation are pale brown or grey and contain many fossils and pieces of flint. Since the dolomite is also grey or pale brown the two are not easily distinguishable by sight when they

FIGURE 1. Physiographic diagram of Southwestern Ontario, giving a bird's-eye picture of the surface form.

appear as pebbles in the till. It will be noticed that in the Essex peninsula the younger strata have been worn away exposing the older limestones of the Norfolk formation.

The bedrocks in Southwestern Ontario lie in the form of a broad half-dome, the northeastern part of which has been removed. They slope upward from Lakes Erie and Huron to the brow of the Niagara Escarpment

at the rate of 20 or 30 feet per mile, while the warp of the strata is well-shown on the Niagara Escarpment. The cap rock rises from an altitude of about 650 feet above sea level along the south shore of Lake Ontario to over 1,700 feet a few miles south of Collingwood then slopes towards the north to less than 800 feet along the east side of the Bruce peninsula. In the Niagara peninsula the Onondaga limestone terminates in a second, low, northward-facing escarpment.

The Niagara Escarpment is the most conspicuous topographic form in peninsular Ontario. The cap rock is a massive dolomite, while the lower slopes are of shale. It was formed by the differential erosion of these two rocks. Here and there along the Georgian Bay the Manitoulin dolomite below the cap-rock extends out to form a shelf that terminates in a second bluff. The structure is illustrated by Figure 10. The area under study includes some level country below the escarpment along Lake Ontario and Georgian Bay.

Along the edge of the Niagara Escarpment a series of stream valleys have been cut into the rocks. The largest, now occupied by the Beaver River extends about 25 miles south to Flesherton from the shore of Georgian Bay. The Dundas valley, running west from the tip of Lake Ontario apparently extends for only 15 miles because it is filled with drift beyond. Other rock valleys partly filled with drift add to the ruggedness of this eastern borderline. Moreover they exerted a definite control over the movement of the glacier as it moulded the surface deposits into their present position and form.

SURFACE DEPOSITS

Depth to Bedrock

There were at least two and probably three glaciations in this region before the Wisconsin which laid down the upper drift. The older materials often come to light in stream cuts and in the shorecliffs of the Great Lakes. In comparison with Wisconsin materials they are bluish rather than brownish and more compacted. We have little information about the older tills and interglacial strata, but they at least affect the depth to bedrock.

The bedrock is at the surface or at no great depth along the top of the Niagara and Onondaga escarpments, and the depth of drift increases towards the southwest. In the extreme southwest, outcrops of limestone near the Detroit River and on Pelee Island are exceptions to this rule. In the counties bordering Lake Erie there are many gas and oil wells, and the driller's logs which note the depth to rock are published in the Summary Reports of the Geological Survey of Canada. One log, south of Chatham, reports 260 feet of overburden. In western Norfolk county all six of the records obtained show between 215 and 259 feet of unconsolidated material. Along the shore of Lake Huron, except north of Southampton, 100 feet to rock is about average. In the Kitchener vicinity the depth is indicated by figures of 178 and 194 feet a few miles west of that city. In the northern half of the area the drift is shallower than in these localities and the bedrock often is exposed in stream valleys at less than 100 feet below the level of the surrounding country.

Outline of Wisconsin Glaciation

From the standpoint of glacial geology the main points in the history of the recession of the last glacier have long since been established. The writings of Taylor, Leverett, Spencer, Goldthwaite, Coleman, Johnson, Stanley and Maclachlan are full of interest to anyone wishing to read about local glacial history. Of these the works of Mr. F. B. Taylor, an American who made most of his excursions into Canada at his own expense, are classical. More recently Mr. F. F. Morwick of the Ontario Agricultural

FIGURE 2. Key map showing landmarks mentioned in the text.

College, during the course of soil surveys, has accumulated a wealth of detail about glacial lake and glacial features in the southern part of this area which was made available to us.

With the information from all these sources as a background, the writers in their field work during the summers of 1940, 1941 and 1942 were able to fill in some of the gaps left by former investigators, so that fairly complete

and accurate maps of all the glacial features may now be drawn. We have on occasion differed with previous writings but as far as possible in this article controversy has been avoided.

The Wisconsin glacier covered all of Ontario including the highest parts of Grey and the Bruce Peninsula. Nowhere was any evidence found of a difference in soil age like that seen at the edge of the Wisconsin till sheet in southern Ohio. The promontory southwest of Collingwood undoubtedly diverted the flow of ice in two directions around the highland of Grey and Dufferin and this was the first land to be uncovered during the recession. The absence of an interlobate moraine on the central part of the upland is interpreted to mean that the ice sheet stagnated and melted off, while outside this plain the surface was moulded by two tongues of ice, one entering the Huron and the other the Erie basin. For a time they met head-on near London and as they withdrew minor readvances by either lobe created a series of parallel moraines to the north and south of that city. After uncovering nearly all the peninsula there was a general readvance and a great horseshoe-shaped moraine was built around the shoulder of the higher land. This system is composed of two main strands with additional minor strands in some places. From this position the glacier gradually receded with only one or two short interruptions until it was beyond the limits of the area.

From the time the lobes separated to unburden the land southwest of London the lower areas in the Huron and Erie basins were under water. During this time the St. Lawrence Valley was blocked with ice so that the lake basins filled to higher levels than at present before finding outlets. Four of these, one at Imlay, two near Ubly on The Thumb and a fourth and lowest at Grand Rapids carried the drainage across Michigan to the Mississippi. Further retreat of the glacier permitted the waters of the Huron Basin to drain eastward into the St. Lawrence system through two outlets. The first was by way of the Kawartha Lakes and the Trent River and the other through the Mattawa Valley from North Bay to the Ottawa River. As long as the St. Lawrence Valley was blocked with ice a higher, larger lake stood in the Ontario Basin with its outlet at Rome, N.Y. into the Mohawk Valley.

Each of these lakes formed beaches of gravel or sand or cut shore-cliffs to mark their limits. Further evidence is to be seen in the delta sands occurring at the mouths of the rivers and in the stratified silts and clays farther out in the old lake plains.

Moraines

The centre-piece among glacial features of Southwestern Ontario is the Horseshoe moraine. This complex moraine system and the abandoned stream channels produced by contemporary drainage appear conspicuously on the moraine map (Figure 4). This map varies considerably from Taylor's maps and also distinguishes between moraines that were pushed into position by an advance of the glacier (till moraines) and those that were deposited by meltwater along a stationary or receding ice front (kame moraines). The former are mostly of boulder clay while the latter consist of roughly stratified sand, gravel or cobbles.

One can hardly fail to notice the similarity in the arrangment of kame moraines and spillways on the east and west sides of the central plain. The action of the Huron lobe on one hand resembled that of the eastern tongue on the other. And the drumlins around Teeswater balance the drumlins north of Guelph adding to the similarity.

The western limb of the Horseshoe moraine enters Michigan just south of Port Huron, where it is called the Port Huron moraine; on the eastern side the strands pass near Paris and Galt and were given these names by Taylor (16). Its character is not uniform throughout. From Walkerton

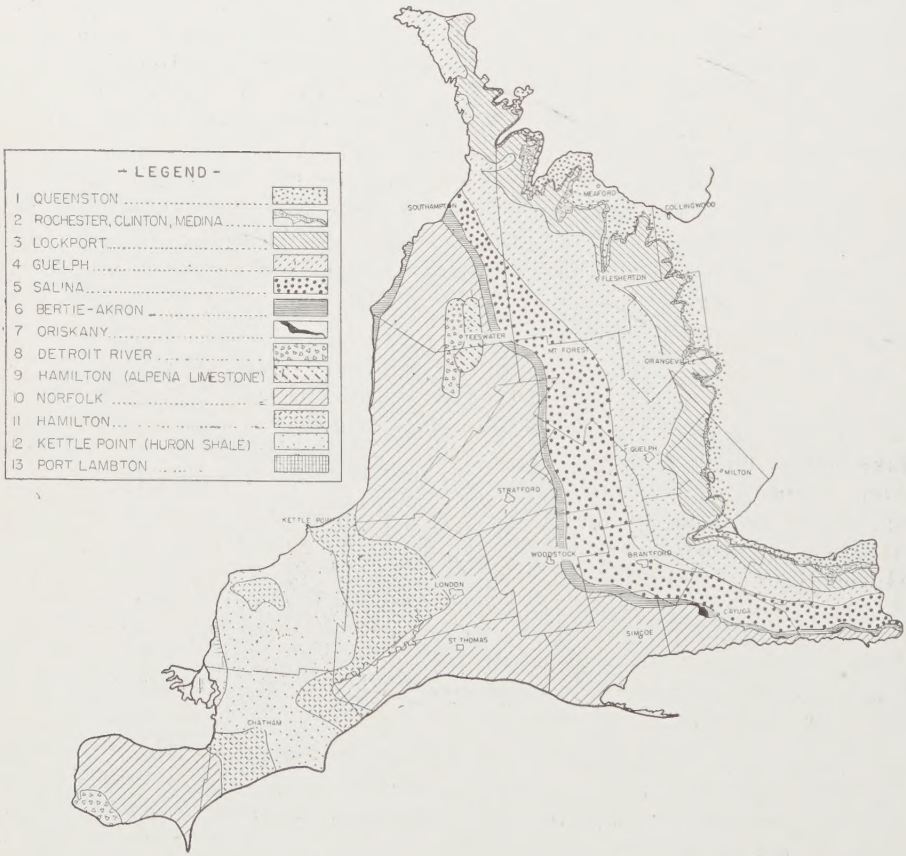

FIGURE 3. Bedrock map compiled from several maps of the Geological Survey of Canada.

up the slope to the Escarpment then southward as far as Brantford the strands are rugged and stony with occasional sandhills. On the Lake Huron slope they are less rugged and are composed of heavy boulder clay. The character of the material and the presence of stratified clays between these moraines and the Huron shore suggest that the glacier built the ridges by pushing up clay from previously deposited beds. The extremities of both limbs, south of Exeter and of Brantford, were built under the water of glacial Lake Whittlesey and therefore are much smoother than land-laid moraines. In fact the western limb is too faint to be seen west of Wyoming.

The moraines north and south of London are also of boulder clay, containing a high proportion of limestone from the Norfolk formation. Those around the western end of Lake Ontario are also clay ridges containing a good deal of red shale from the Queenston and Medina formations. The low clay moraines south of Chatham contain black shale from the Hamilton formation.

The kame moraines provide some of our roughest topography. As seen on Figure 4 their distribution is irregular, yet most of them are grouped in two belts before the Horseshoe moraine to the northwest and southeast

FIGURE 4. Map of moraines and spillways.

of the central plain. A favourite place for their formation is along the sides of valleys. They occur along the Niagara Escarpment, at the heads of the valleys which indent it, for instance at Flesherton west of Dundas and at Fonthill, and at these places the outwash sands which are invariably associated with kames are present in typical form.

The spillways that carried the drainage from the melting glacier downslope along its edge are common features of the landscape in Southwestern Ontario. When mapped as in Figure 4 they appear as a network in front

of the Horseshoe moraine and as strips along the side of the Niagara Escarpment. While the moraines stand above the surrounding plain the spillways, on the contrary, occupy depressions. These troughs are partly of their own making and are floored with beds of gravel or accumulations of muck. The gravel terraces are often at two or more levels, the lower ones being within the higher. The streams flowing in them are misfits, being far too small to have produced the broad channels to which they are confined. These points are illustrated by a block diagram, drawn to scale, of the spillway that runs southward past the village of Hillsburg. From this impressive size they grade to very small dimensions.

On the eastern side of the central plain the Thames, Grand and other rivers flow through glacial spillways. Near Honeywood a sandy basin of a few thousand acres marks the upper end of this set of spillways. The

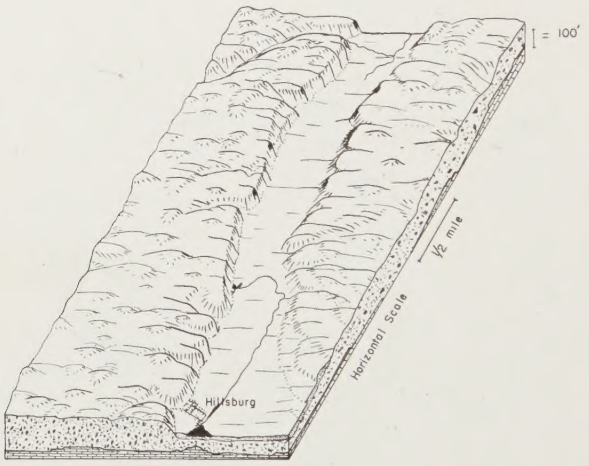

FIGURE 5. Block diagram of the glacial drainage channel at Hillsburg, Ont.

Grand meanders over gravel terraces, while the Thames runs within definite troughs worn in the till plain. On the western and northern sides of the upland the Ausable, Maitland and especially the Saugeen rivers are similarly confined, through part of their lengths, to the broad spillways floored with gravel, sand or muck. West of Walkerton, the Greenock swamp developed in a pocket of the spillway at the bend of the moraine. When the ice front stood near Teeswater, drainage flowed directly away from it, southward, and a good deal of outwash was laid down between the hills.

The last of the glacial streams in this area left their mark in a peculiar manner. Along the slopes of The Escarpment sand or gravel was deposited in spillways between the glacier and the hillside to the west in the form of terraces when the glacier withdrew. In the valleys of the Nottawasaga, Pine and Mad rivers these beds are very deep. Their flat-topped character

is preserved in part only; some sections have been cut through by gullies, while wind erosion has added to their mutilation. Incidentally, the sand removed was spread out again in glacial Lake Algonquin to form the sand flats around Camp Borden and Alliston. Most of the terraces are north of the Oak Ridges moraine of Central Ontario which abuts the Escarpment just south of Orangeville. South of this there are only a few trains of gravel such as that in the vicinity of Georgetown and just east of Campbellville.

The area covered by spillways is nearly as large as that occupied by moraines. The swampy portions are seldom cleared and are adapted to white cedar, while the deeper beds of sand or gravel have engendered some very good soil.

Till Plains

The till plains are definitely related to the sheet of boulder-clay or boulder loam spread over the surface by the Wisconsin ice sheet. It covered all the area except the few patches near the escarpments and on Pelee Island where the bedrock was swept clean. We have already seen that moraines and spillways, which were products of the recession, have modified or buried much of the ground moraine; and we will later point out the areas which received locustrine sands or clays to bury the till. First, however, let us deal with the unmodified parts of the ground moraine. Since they have generally smooth topography they may be called till plains.

The most interesting parts of the till plains are the drumlinized sections. Here the till was moulded into many oval hills with their long axes always aligned with the direction of movement of the ice sheet. Their distribution is shown by Figure 6. It will be seen that both the Huron and the Eastern lobes left drumlins although more of them were shaped by the former. A rough estimate of the number of drumlins in the whole area is 2,000, made up as follows: about 500 in Arran and adjacent townships west of Owen Sound, at least 1,000 in the rest of the large "field" in Grey and Bruce, about 400 in the Guelph area and 60 in the small group south of Caledonia. This is only half as many as are estimated to be in the central part of the province north of Lake Ontario. With the exception of the groups west of Owen Sound and in the Bighead Valley near Meaford the drumlins are more widely scattered than in Central Ontario.

The orientation of the drumlins is also shown in Figure 6. They fan out radially around the end of Lake Ontario, depicting the movement of an ice tongue in that basin. In the Walkerton vicinity a change of direction inside and outside of the Horseshoe moraine is evident, while west of Owen Sound there is a further reorientation. The positions of the drumlins and the moraines are the main items used in piecing together the history of a glacier's recession.

The drumlin symbols on the map are not drawn to scale. The majority of these hills are one-half to three-quarters of a mile in length and one-quarter to one-third of a mile wide. West of Owen Sound they are of the long, narrow type, while in the Bighead Valley near Meaford they are oval and very large.

Near Teeswater the flats between the drumlins are often floored with gravel or sand. This is stream gravel or outwash. North of Guelph there is a network of spillways running across the grain of the drumlin field. The drumlins south of Caledonia were submerged in a glacial lake after their formation and stratified clay was deposited between them. Some were completely buried, others have only their crests exposed while the clay encroaches upon the sides of them all. In parts of Arran township also drumlins and clay flats are associated.

FIGURE 6. Drumlins and eskers. The oval dots are symbols showing the orientation of the drumlins, but they do not locate and outline them exactly.

Figure 6 shows eskers in addition to drumlins and it is apparent that they are frequently associated. Eskers are knobby ridges of sand or gravel and are closely related to kames. They may be considered to be chains of elongated kames superimposed upon the till sheet. They take a crooked course across the till plains, and are conspicuous on account of their topographic form and the coarse material of which they consist.

Between Mount Forest and Shelburne a series of eskers is situated. The one running from Mount Forest to Grand Valley was mentioned by Taylor in 1908 (15). These were formed under the influence of ice from the Huron basin. The longest of these ridges formed by the other ice lobe runs from College Hill at Guelph towards Elmira.

The undrumlinized parts of the till plains can be divided into several sections on the basis of depth to rock, topography, or the character of the till.

Along the brow of the Niagara Escarpment the till is frequently shallow or absent. It was swept off the prominence by the advancing glacier. In Welland and Haldimand counties there are similar shallow limestone plains scattered along the Onondaga escarpment, and small outcrops of limestone occur near Amherstburg and on Pelee Island. Excessive stoniness is also common where the till is scanty, which further reduces the value of the soil. Only a small proportion of this land is cultivated, nearly half is in rough pasture and the remainder is still in forest.

In the high, till plain northwest of Arthur the drift is not deep enough for drainage to become established. Its main drainage outlet is the Grand River and, as seen at Grand Valley, the deepening of its channel has been held up by a floor of dolomite. As a result of inhibited drainage, swamps are numerous and other wet land just as common. One is bound to remark here about the "willow flats" that characterize this plain. The wet land that was cleared then relegated to permanent pasture has invariably produced a growth of dwarf willows.

Southwest of Arthur the drift is deeper, the topography more rolling and the willow flats not so numerous. However, drainage is still far from perfect. At Arthur the till is a sandy boulder clay consisting mostly of dolomite, and it gradually gets heavier until the brown clay till of the Huron slope is reached. South of Atwood, around the Ellice swamp north of Stratford, and southeast of Tavistock, three tracts having a layer of stratified clay and silt on the till are situated. This clay was probably deposited in shallow pondings during the retreat of glacier. In Oxford county at the southern part of the central plain the drift is deep, the topography quite rolling and the material in the upper till is a pale brown calcareous loam.

Below the Horseshoe moraine there are two types of clay till, one on the Lake Huron slope and the other below the "Blue Mountain" around the Georgian Bay. The first type is found in a narrow strip between the Horseshoe moraine and the beach of glacial Lake Warren, widening north of Kincardine beyond the reaches of Lake Warren. It is a pale brown calcareous clay containing comparatively few pebbles. Below this sheet of till, which averages about 6 feet in depth, it is not unusual to find a crumpled bed of stratified clay which was probably the main source of the clay in the till above.

Between Owen Sound and Nottawasaga Bay a shallow layer of red, shaly till is found on the shale at the base of the escarpment. In the Bighead and Beaver Valleys, near Meaford and Thornbury, the till is deeper and contains more limestone and hard silicious rocks from the north than the shallower till.

The till plains, altogether, cover about 3,800,000 acres, which is nearly 40% of the total area. This means that the till in over 60% of the area is modified or buried by glacial drainage channels, moraines, lake-laid sediments or peat. In fact, glacial and post-glacial lakes at seven main levels covered about four and one-quarter million acres of Southwestern Ontario.

FIGURE 7. Map of shore features—beaches, bluffs and indistinct shorelines.

Glacial Lake Deposits

A map of shore features is given in Figure 7. It specifies the existence of a beach, shorecliff and boulder pavement or a featureless shoreline. In comparison with Leveretts map (8) there are added details and a few changes in the location of the shorelines. Some of these changes agree with MacLachlan who studied the levels of these beaches in considerable detail (9). On the other hand they more often concur with the unpublished maps of Mr. F. F. Morwick of the Ontario Agricultural College.

The first and highest of the glacial lakes in the Great Lakes basin is Lake Maumee, named after a watershed in northwestern Ohio. During the existence of this lake the Huron and Erie ice lobes met so as to cover all the land below London. North and east of that point, the two lobes separated, exposing the land between them. From the city of London eastward for 8 miles there are stratified sediments that must have settled in standing water. The airport at Crumlin is on interstratified sand and clay. In Ohio the Maumee beach is about 50 feet higher than the next one below it. This ponding at London is 100 feet above the next (Whittlesey) beach, about 925 as compared to 825 feet; its outlet was over the ice along the line of contact between the two lobes and it is suggested that it was a contemporary of Lake Maumee. It did not form any distinctive shore features, but the limits of the sediments are quite definite.

The next beach to be formed belonged to Lake Arkona, but since the water later rose again to a higher level and built the Whittlesey beach the latter will be discussed first. From Brantford to Exeter the Whittlesey beach or shorecliff marks the boundary between till plain and lake plain, if we except the small area east of London. The extremities of the beach meet the eastern and western limbs of the Horseshoe moraine at Brantford and Exeter proving that this moraine was built during the time of Lake Whittlesey. The beach itself is not as strong as the one below it, and in a few places where no gravel was available the location of the shoreline is indefinite. However, in Ontario this lake merits fame for its deltas; even though, peculiarly enough, the lack of good deltas in Michigan and Ohio is pointed out by Taylor. The Thames spread sand over Caradoc township west of London, and the border-ice stream, in front of the Paris and Galt moraines, debouched an immense quantity of sand into this lake southwest of Brantford covering most of Norfolk and adjacent parts of Elgin and Oxford counties. It is notable that no such large delta was formed at the mouth of the spillway in front of the western limb of the moraine, only a small one being present south of Exeter.

The highest water of Lake Arkona stood about 30 feet below the Whittlesey level and the lake built three beaches close together. However the Arkona beaches seldom appear as distinct ridges and the gravel is spread out as if by washing. From this and other evidence it is concluded that these beaches were formed before the advent of Lake Whittlesey and were submerged when the water rose to the Whittlesey level. Lesser beaches might have been dispersed beyond recognition when subjected to such wave action, but the Arkona gravel strand is heavier than those just above or below it. Between Arkona and Alvinston and on Ridgetown "island" as seen on Figure (7) it is at its best. Here it gives rise to strips of gravelly soil and furnishes road material from several large pits. South of St.Thomas and west of Sparta there are broad gravel ridges which are considered to belong to Arkona. The fact that the strand west of Sparta is partly buried by stratified silt proves that it was under water for a time. East of Sparta all traces of this beach are lost under the sands of the great delta, mentioned in the last paragraph.

Lake Warren left two beaches, the lower one lying 10 to 15 feet below the upper and never very far away from it. From the Niagara Escarpment north of Hamilton to the other ice barrier north of Kincardine this shoreline

extends for nearly 300 miles. To this may be added 50 miles of beaches around the island on which Ridgetown is situated and a smaller island at Leamington to get its total length. This does not include the Saugeen embayment where there are no beaches or bluffs to be found. Along the Huron slope it replaces the Whittlesey beach as the upper limit of lake plains. Most of the larger rivers of Southwestern Ontario were active during Warren time and each brought down sand and gravel to be debouched into the lake. The delta at the mouth of the Grand River merges with the Whittlesey delta so that is limits cannot be outlined. At the mouth of the Thames there is a huge spread of sand covering part of Middlesex, Elgin Kent and Lambton counties. The Saugeen's delta north of Walkerton covers about 50 square miles and smaller ones were laid down near Goderich and Bayfield by the Maitland and Bayfield rivers.

The most important beds of silt in the region are in the Warren plain on the fringes of the deltas. The largest tracts are found east of Brantford, in southern Elgin county and near Chatham and Blenheim. Stratified clays are found between Brantford and Lake Erie while deep beds of varved clay occur in the Saugeen embayment.

The last of the glacial lakes in the Huron and Ontario basins were named Algonquin and Iroquois respectively, after the Indian tribes that lived in these parts. They were both long-lived enough to develop splendid shore features. Between these and the Warren beach are some fragmentary beaches labelled "Receding Warren" on the map. The importance of these gravel bars is that they interrupt the clay plains of Welland and Essex counties. Perhaps the strip of shallow sand between the Warren beach and Lake Huron also belongs in this category even though typical beach ridges are wanting. The shoreline labelled Elkton marks the limits of the flat lands around Lake St. Clair and so has a special physiographic implication.

The Iroquois shoreline between Hamilton and the Niagara River runs near the base of the Niagara Escarpment. It built its most prominent gravel bar across the mouth of the Dundas Valley, where it now carries the highway and railroad entering Hamilton from the north, also the famous rock gardens. On the west side of Stony Creek is another strong gravel ridge on which some of the finest sweet cherry orchards are set. From the standpoint of sweet cherry production the extent of this beach is far too small. Between St. Catharines and Queenston there is a low bluff cut in boulder clay, and the boulder pavement associated has remained to trouble the farmers.

The deepest sands in the bed of Lake Iroquois occur in the vicinity of Grimsby. They are considered to be the product of wave action because no streams of any size entered this lake here, or anywhere between Hamilton and the Niagara River. Outside the Grimsby area the sand layer where present is seldom more than $2\frac{1}{2}$ feet deep over the clay. Between Grimsby and Hamilton the red shale is at or near the surface in most of the plain giving rise to intractable clay soil.

The Algonquin shoreline from Sarnia to Collingwood is 240 miles long. As seen in Figure 7 it skirts the present shore except where it has been undercut by the present lake and obliterated. Some good gravel beaches were left by this lake; near Thornbury, Meaford and Southampton across

the valleys of the Beaver, Bighead and Saugeen rivers there are huge curving gravel bars, each with several distinct strands at different levels giving a stepped effect. South of Grand Bend a line of dunes has been blown up across the mouth of a lagoon and other dunes formed along the Algonquin shore are seen near Hepworth. Some prominent shorecliffs were also cut by Lake Algonquin, wave action being strong on the east side of the Huron basin. Between Kincardine and Southampton there is a nearly continuous bluff which in places is 100 feet in height. Invariably there is a boulder studded terrace at its base.

This lake is therefore responsible for the uninviting border of land along the shore of Lake Huron, which has spoiled so many attractive farm sites. It has also forced the engineers to build the Blue Water Highway so far from the shore that the beautiful greenish blue waters of the lake are out of sight.

The last of the extinct lakes is called Nipissing because its outlet was east of North Bay at the head of the lake that now bears this name. Around Georgian Bay its shorecliffs, boulder pavements or shingle beaches are fairly continuous; along Lake Huron many of them have been obliterated by the waves of the present lake. On the Bruce Peninsula, near Lion Head, part of Eastnor Township was low enough to be under Nipissing water and a level tract of silt and clay resulted, contrasting strongly with the unmantled rocks on either side and giving rise to the only farming section of note north of Wiarton.

Between Lowbanks on Lake Erie and the city of Welland is a low-lying, flat tract that includes the Humberstone Peat Bog. The surface is less than 10 feet above the present level of Lake Erie and apparently it was covered by the lake at an earlier period in its history. The lowering of Lake Erie sufficiently to uncover this plain is thought to be due to the deepening of the outlet at Fort Erie. A distinct shore terrace is to be seen at Lowbanks but elsewhere the margin is vaguely defined. Around the deeper parts of the bog there are patches of shallow muck in places overlying marl; and beds of calcareous sand silt or clay.

Another tract with topography "flat as a floor" borders Lake St. Clair. Between Dresden and the St. Clair River its limits are marked by a faint but continuous shoreline near the 600 foot contour relating it to a former lake in the St. Clair basin. The shoreline is also found in Michigan and was called Elkton by Leverett (7). Within this tract, as in the Humberstone area the beds are often highly calcareous, and soil profile development is feeble indicating that the sediments are of recent origin. Drainage has been established by means of municipal ditches which are now an integral part of the landscape.

North of Harrow, as shown on Figure 8, there is another level tract at a slightly higher level. The beds are of very fine clay containing less lime than those just described.

Some parts of the lake plains have very little stratified material over the till sheet. These parts may be called bevelled till plains, the bevelling being due to the lowering of the knolls by wave action and the building up

of the depressions with clay. The distribution of bevelled till is shown on Figure 8. In Essex and Lambton counties the exposures, with few exceptions, show boulder clay. The water-laid layer on the surface, if present, is weathered so that the stratifications are no longer visible. However, in the Niagara peninsula and on the Huron slope the till is not very distinctive, being merely reworked clay from stratified beds below. From the standpoint of soils, therefore, this material need not be separated from lacustrine clays.

FIGURE 8. Map of lacustrine clay areas.

RECENT DEPOSITS

Shoreline Features

Peat or muck, marl, blowsand, alluvium of existing rivers and the shore features of the present lakes are the most recent surface deposits or forms. The south shore of Georgian Bay is littered with boulders, except just east of Meaford where a bluff is cut in the shale and in the few spots where sandy beaches occur. The Georgian Bay side of the Bruce Peninsula terminates in sheer rock cliffs in direct contrast to the strand line on the Lake Huron side where the rocks gradually dip below the lake. On Lake Huron there are several good sand beaches between Sauble Beach and Grand Bend

although shorecliffs and bouldery beaches are much more in evidence. The bluffs reach a height of 100 feet near Goderich. At Kettle Point, Clark Point, Inverhuron and other places the bedrock is exposed.

The Lake Erie shore is famous for its three sand spits at Point Pelee, Rondeau Park and Long Point. They separate three concave segments of shore. At Port Stanley, in the centre of the biggest "bite" the bluffs are 125 feet high. Some idea of the structure may be obtained from Figure 1. It is apparent that the shoreline has been eroded by wave action and it is interesting to speculate on the width to which the lake has encroached upon the land at this point. If a crow flew from Long Point to Rondeau Park, it would pass about 10 miles from Port Stanley. A straight line projected along the grade of the plain which borders the lake would drop between 10 and 15 feet per mile from the bluff at Port Stanley to meet the water of lake about 10 miles from the shore. According to the municipal maps and records at Port Stanley the bluff is receding nearly three and one-half feet a year. Assuming that Lake Erie has existed for 15,000 years it would at this rate have worn back the bluffs for about 10 miles. For these reasons we think that the shore was originally about 10 miles to the south of its present position at Port Stanley.

East of Port Dover the rock is often exposed and the bluffs are lower than they are farther west. The shore of Lake Ontario is similar, having low shorecliffs cut in boulder clay or shale with beaches built across the mouths of lagoons, as at Port Dalhousie and Jordan Harbour. Across the mouth of Burlington Bay is a well-known barrier beach called the Burlington Beach.

On the shores of Lake Huron and Erie there are outstanding lines of sand dunes at several locations. The three sand spits of Lake Erie each have some dunes. West of Crystal Beach for 12 miles they are extensively developed. Near Port Burwell a huge dune called the Houghton Sandhills illustrates well the action of shifting sand as it buries the trees and fences and spoils the land for agriculture. On Lake Huron the live dunes are best developed between Grand Bend and Kettle Point, while they are also found at Inverhuron and Sauble Beach.

Blowsand

In addition to the dunes on the lake shores, blowsand is frequently found in the sandy areas throughout the region. Fixed dunes along the ancient shorelines may be rejuvenated, as many have been in the counties bordering Lake Erie. Blowsand is common throughout the delta sands. The kame moraines are subject to blowing if stripped of protective cover, and the sandy terraces along the Niagara Escarpment north of Orangeville are not always stable in the face of wind action.

Alluvium

As a rule, the rivers of Southwestern Ontario have only gentle grades, and they meander over flood plains between bluffs after the fashion of slow-flowing streams. In springtime, or other times of flood, the bottom lands receive a dressing of alluvium preventing the development of normal soils. The alluvium may be of silt, sand or gravel. It is a mixture of top-soil and raw subsoil so that it contains some humus. In this region it

invariably contains plenty of limestone or dolomite. Most of this material comes from bluffs along the river or out of gullies in the nearby slopes. The establishment of a cover of trees or sod to protect these sites is a matter that has recently come into great prominence.

Two special cases should be mentioned when discussing alluvium, that of the clay deposited on the banks of the Thames in Kent county and the silt and sand of the St. Clair delta. In the level country below Thamesville periodic floods have produced faint levees in which the clay is pale reddish brown, distinguishing it from the brownish grey clay of that area. The material in the "birds-foot" delta at the mouth of the St. Clair River is little weathered and is classed with alluvium rather than delta sands. It is highly calcareous and contains considerable organic matter.

Along Lakes Erie and Huron where there are high bluffs to provide the fall a series of short rapid streams have developed, and they have cut abrupt V-shaped valleys which dissect the plains adjoining these lakes. Similar valleys are cut by the small streams which flow over the Niagara escarpment.

Peat and Muck

The poorly drained basins in which peat or muck has accumulated are numerous in the high plain between Arthur and Singhampton. Because of the gentle grades and the presence of solid rock at no great depth, drainage channels are poorly developed. Many small bogs occur in the kettles on the moraines, and in the abandoned glacial spillways are long wet troughs in which cedar swamps are found. On the slopes outside the upland, swamps are conspicuously scarce, as they are on the southerly slope north of Lake Ontario. This is because of deeper drift, a little steeper grade, or the planing effect of the glacial lakes on the lowlands, all of which help the drainage. However, a large bog lies in the depression below the Onondaga Escarpment south of Welland and another one, called the Greenock Swamp, has developed west of Walkerton in a pocket where drainage was impeded by the Horseshoe moraine. On the South shore of Lake Huron are two valuable marshes in lagoons near Thedford and Blackwell, and a similar tract of muck called the Erieau Marsh is located behind the sand spit at Rondeau.

PHYSIOGRAPHIC DIVISION

In the foregoing paragraphs the various landforms of Southwestern Ontario have been segregated and described. For the purpose of giving a simplified picture of the landscape, seven physiographic types have been set up and mapped in Figure 9.

1. *Escarpment*

The face of the Niagara Escarpment exhibits a terrain not found elsewhere in Ontario. The bluffs along the brow are of dolomite and the slopes below carved in red shale. It extends for well over 200 miles from the Niagara River to Owen Sound. North of Owen Sound the Escarpment is present at or near the Georgian Bay shore, but the strip to be mapped is so narrow that it has not been shown. Surrounded by a glaciated landscape this pre-glacial land form is quite distinctive. The long uniform

slope presents a great contrast with the knobby irregular hills found on the moraines. The stream valleys which indent it also resemble those of unglaciated territory.

Between Honeywood and Orangeville there is a stretch where the escarpment is buried by glacial drift piled against it from the east. South of Orangeville, in Caledon township, only the upper part remains uncovered.

The steepness of the slope has prevented clearing for agriculture in some places, particularly in the vicinity of Georgian Bay. Where the land is cleared the farmers usually face problems of soil erosion and droughtiness that are common in non-glaciated regions.

FIGURE 9. Physiographic divisions of Southwestern Ontario.

2. *Limestone Plains*

In many places along the brow of the Niagara and Onondaga escarpments the limestones are swept clear, or nearly clear of overburden. There are approximately one-half million acres of limestone plains, most of which are in the Bruce peninsula. The surface is usually sprinkled with blocks of dolomite or other stones. There are also numerous small swamps.

There is no need to stress the limitations imposed on farming by shallow rocky soil interrupted frequently by swamps. The poorer tracts can be left to produce maples and other hardwoods, while much of the cleared land will be pastured. Very little is fit for intensive cultivation.

3. *Morainic Hills*

Morainic hills characterize a horseshoe-shaped belt of one and one-half million acres that surrounds a high, central plain and separates it from the lower plains flanking the lakes. Some of the smoother moraines are excluded from this category, while on the other hand the drainage channels associated with the moraines are unavoidably included. The clay ridges on the Huron slope are relatively smooth moraines, while the kame moraines provide some of the roughest topography. For the most part the material in this drift comes largely from the underlying bedrock. Stoniness is general.

The knob and kettle topography, where most pronounced, imposes a severe limitation on agriculture, because it results in small irregular fields and hillsides that are subject to erosion. On the smoother, less stony ridges a good many fine stock farms have developed.

4. *Till Plains*

More than one-third, or 3,840,000 acres of this peninsular part of Ontario consists of till plains. The broad tract lying inside the moraines on the long slope from the height of land to the vicinity of London is not drumlinized. It is an undulating plain, beset with swamps in the higher part, with only an occasional esker to break the monotonous topography. Around Guelph and Teeswater there are drumlin fields often with gravel and sand in the hollows between the drumlins. North of the Horseshoe moraine in Grey and Bruce counties, the till plain is drumlinized except in a few places near Georgian Bay and Lake Huron. Some of the smoother clay moraines south of Lake Huron are also mapped as till plains.

Some details as to the materials comprising the drift in various sections are summarized in Table I.

Two or three general conclusions about the composition of the till of this area can be stated. Although it is not so high in lime as the till in much of central Ontario (10) it invariably contains carbonates, usually in abundance. The bulk of the material comes from the underlying rocks, but there are notable exceptions to this rule. The high clay content of the till in a broad belt bordering Lake Huron and Lake Erie is also worth mentioning because Wisconsin till is commonly more sandy (3).

Many types of soil are found within the till plains, differing in topography, drainage, texture and the composition of their parent materials. In fact some of the poorest and some of the best land in the area is represented.

5. *Clay Plains*

The clay plains are represented by the squares on Figure 9, and they occupy the lowlands bordering the lakes. They are estimated to have an area of 2,750,000 acres although this includes many small tracts with sand on the surface. None of this territory has much relief and some of it is flat. Between Lake Ontario and the Grand River there is rolling topography, while the silty flats around Lake St. Clair, southwest of Welland and near Lion Head represent the other extreme. Deep beds of stratified clay occur north of Walkerton, south of Brantford and in Middlesex county.

East of Brantford, south of St. Thomas and Blenheim and near Chatham good beds of silt are found. Much of the plain in Essex, Lambton and along Lake Huron has only a shallow deposit of clay so that much of the soil is developed on the till.

TABLE 1.—TILLS OF SOUTHWESTERN ONTARIO

Name	Location	Composition
Vinemount	In a belt 1–5 miles wide along the brow of the Niagara Escarpment.	Red shale and sandstone from the Queenston and Medina formations mixed with Lockport dolomite. Usually stony.
Dundalk	In the high plain northeast of Arthur.	Covering on bedrock is rather shallow. Till is a sandy clay consisting mostly of local dolomite.
Milverton	In the plain southwest of Arthur.	Clay content increases towards the southwest. There is not a belt of shaly till over the Salina formation, as might be expected. Material is all highly calcareous due chiefly to material from the Guelph and Norfolk formations.
Oxford	In Oxford County.	Calcareous, pale brown, loamy till.
Eramosa	In drumlin field between Guelph and Caledon.	Stony loam, mostly of local dolomite.
Teeswater	In drumlin field south of Walkerton in southern Bruce and northern Huron.	Stony loam, mostly of local limestone.
Huron	In a strip on the Lake Huron slope between Goderich and Southampton.	Brown, calcareous, heavy clay till; much of the material reworked from previously-deposited beds of stratified clay.
Grey	In the large drumlinized belt lying north of the Horseshoe moraine in Grey and Bruce.	Stony loam characterized by dolomite, except in the Bighead Valley where till is like that in the Beaver Valley.
Beaver Valley	In the Beaver and Bighead Valleys.	Mixture of Queenston and Medina shale and sandstone with limestone and siliceous rock from the north.
Cape Rich	In a belt bordering Georgian Bay between Owen Sound and Thornbury.	Shallow till, consisting largely of red shale from the underlying rock.
Essex	In Essex County, where till appears at the surface.	Has highest content of siliceous rock of any till in Southwestern Ontario. Is a drab calcareous clay loam.
Lambton	Lambton County.	Drab, calcareous clay containing some shale and pebbles of flint.
Ridgetown	On the Ridgetown-Blenheim moraine.	Grey, shaly clay.

6. Sand Plains

The sands are in scattered locations. The most important tracts, shown in Figure 9, cover one and one-half million acres or about the same area as the moraines. By far the most extensive tract borders on Lake Erie in Norfolk, Elgin, Kent and adjacent counties. These are delta sands deposited in glacial Lakes Whittlesey and Warren and they occupy well over a million acres. The Thames River delta in Lake Whittlesey, known as the Caradoc Sands occupies 82,000 acres, while the Saugeen delta in Lake Warren adds another 24,000 acres. The sand west of Welland was brought there by the Grand River, but the smaller tract lying north of

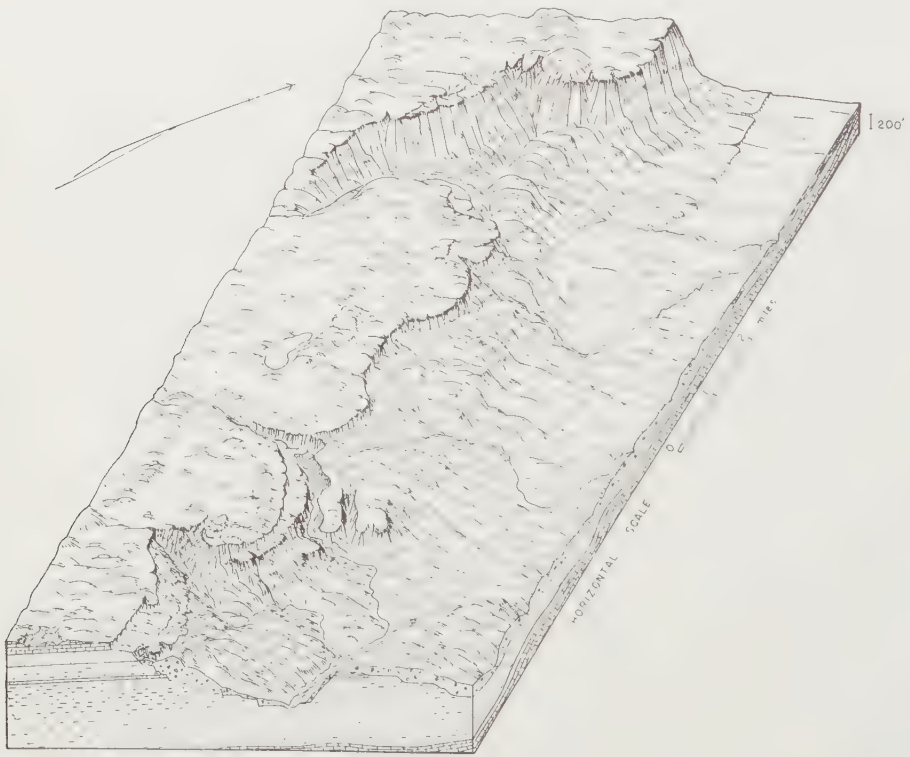

FIGURE 10. Block diagram of the "Blue Mountain" south of Collingwood.

this city is thought to be glacio-fluvial in origin. Similar outwash sand is found around Honeywood. In the Niagara Fruit Belt the sands are usually shallow over the clay and have a reddish colour due to Queenston shale. The patches between Meaford and Collingwood and near Leamington and Harrow are small but nevertheless important for special crops, principally apples along the Georgian Bay and early truck crops in the Leamington district. In fact the incidence of sand plains have with few exceptions resulted in the culture of special crops. Finally, it is worth noting that sand plains usually provide plenty of well water, which is not always the case on a clay plain.

7. *Marshes and Bogs*

In this region swamps and bogs are most frequent in the high central plain. The Luther bog is the largest, with an area of over 20 square miles. Some peat moss was mined from this deposit but the venture has been discontinued. However, only a small proportion of this bog is of sphagnum peat; most of it supports trees and contains more highly decomposed material. Lesser swamps of all sizes serve merely to break the continuity of the farmland on this plateau, and to serve as catch basins for water.

Outside the central plain, swamps are relatively scarce, but the important ones can be pointed out. The Humberstone bog is about half the size of the Luther swamp and lies in a depression north of the Onondaga escarpment. It contains a good deal of sphagnum peat. In Greenock township a big swamp of over 15 square miles has formed just inside the bend of the Horseshoe moraine. It contains shallow, more highly decomposed deposits, similar to those found on the fringes of the two bogs just mentioned. Near Thedford and Blackwell on the southern shore of Lake Huron, are two marshes in lagoons behind sandy barrier beaches. They contain muck, in places underlain by marl. Both marshes have been drained and reclaimed for intensive farming. Like the Erieau marsh south of Blenheim they are used to produce such crops as celery and onions.

SUMMARY

Southwestern Ontario is an elephant-shaped peninsula of slightly over ten million acres lying between the Great Lakes and the Niagara Escarpment. The build of this area and the major land forms are shown pictorially by means of a physiographic map.

This is a glaciated region and, with the exception of the escarpments which are due to differential erosion of the bedrocks, most of the surface features are the result of glacial action. The centre-piece among glacial features is a horseshoe-shaped moraine around the high land. A sketch map shows this moraine system together with the other till moraines and the kame moraines in considerable detail. It also traces the glacial drainage channels which were formed when the ice sheet was melting and receding from the area.

The continental glacier laid down a sheet of unassorted materials over all the area, except in those places along the brow of the Niagara and Onondaga escarpments where it swept the bedrock bare. In some sections it moulded the till into drumlins, the distribution and orientation of which are shown in a second sketch map. The eskers are also shown on this map.

As the glacier receded from Southwestern Ontario a series of ice-dammed lakes at seven main levels, temporarily inundated the lowlands. The abandoned shorelines of these glacial lakes, that is, the beach ridges or shorecliffs and boulder terraces, are mapped in another figure. This is a more detailed map of shorelines than any formerly published. It is useful in discussing the extensive sandy deltas, which are associated. When dealing with the water-laid clays a supplementary sketch map that separates the shallow deposits from the deeper beds and outlines the flat tracts is given.

The shorelines of the Great Lakes which are on three sides of peninsular Ontario are described briefly. Bold shorecliffs and boulder terraces are common to Lake Huron and Georgian Bay. Some special attention is given to the scalloped shoreline of Lake Erie.

The depth of the drift within the area increases towards the southwest. Fortunately some data on the depth to bedrock are available for the southwestern section, since copies of the logs kept by the gas and oil well-drillers are published. Between Point Pelee and Long Point the drift north of Lake Erie is mostly between 150 and 250 feet in thickness.

The composition of the surface materials directly affects soil type and is therefore discussed. Generally, the bulk of the material in the glacial till came from the underlying rocks, although the shale from the Salina formation has no appreciable influence on the till between Brantford and Southampton. Along the boundaries of the formations there is a mixture caused by "glacial drag" off the formation lying to the north or east. In Essex county an unusually high content of silicious rock from the Canadian Shield is found. Much of the lacustrine sand and clay is imported from higher lands, nevertheless, the influence of the bedrock is often manifest.

In post-glacial times beds of peat and muck have accumulated in various shallow depressions. In some instances also deposits of marl are found.

The complex mosaic of surface features has been generalized into seven physiographic types, including the Escarpment, Limestone Plains, Morainic Hills, Till Plains, Clay Plains, Sand Plains, Marshes and Bogs, which have been mapped in Figure 9 and brief descriptions of which are given.

In this account of land forms and geological materials, occasional mention is made of the soils and related agriculture. Much more remains to be done in order to achieve complete adjustment between crops and environment. Indeed this work is only the first step in the study of the use of land.

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VARIETAL SUSCEPTIBILITY TO KERNEL SMUDGE IN WHEAT[1]

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Kernel smudge or "black point" is a disease of the kernel in wheat, barley and rye. In wheat, it is characterized by a light or dark brown discoloration caused by fungi in any part of the grain, and more particularly in the region of the embryo. The fungi chiefly associated in Western Canada with this condition are species of *Alternaria* and *Helminthosporium sativum* P.K. & B. (7). Macroscopically, the *Alternaria* type of kernel smudge is difficult to distinguish from the *Helminthosporium* type. The former, however, does not affect to any appreciable extent the germinability of the affected seeds, the emergence of seedlings, intensity of seedling blight, or yield of the subsequent crop; whereas the latter usually reduces germination, seedling emergence, and yield, and increases the amount of seedling blight and root rot. Both types of the disease, however, discolour the grain, lower the commercial grade, and reduce the value of a wheat crop.

Harris and Sibbitt (6) studied the effect of "black point" upon the quality of durum wheat and found that the presence of heavily damaged kernels in the grain adversely affected the quality of processed durum wheat (semolina and macaroni). The chief effects observed were the occurrence of many black specks in the semolina, and an appreciable impairment of the colour of the macaroni. As these workers have pointed out, millers of durum wheat find it difficult to effect a clean separation of the dark specks in the milling process and therefore avoid purchasing lots of durum wheat that are affected with kernel smudge.

Hard red spring wheat affected with kernel smudge produces a greyish coloured bread and is of inferior quality for milling purposes. Such wheat is usually degraded according to the number of kernels affected and the intensity of kernel infection. Under Canadian Grain Standards, for instance, the presence of more than 5% of smudged kernels in spring wheat lowers the commercial grade from No. 1 Northern to No. 2 Northern. If more than 10% of the kernels is discoloured the grade is lowered from No. 2 to No. 3 Northern. The maximum amount of black-pointed kernels allowed in No. 3 Northern is 15%.

Bolley (1), Dastur (2), and others observed that wheat varieties differ markedly in their susceptibility to certain types of seed discoloration. Evans (3) and Weniger (11) reported that varieties of wheat belonging to the *Triticum durum* group were more susceptible to seed discoloration than were varieties of the *T. vulgare* group. Machacek and Greaney (7) examined a number of wheat varieties, grown at Winnipeg, Manitoba, from 1929 to 1935, and found that *durum* wheat varieties were more susceptible to

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kernel smudge than were the *vulgare* varieties. In a study of the reaction to this disease of several pure lines of a number of *durum* × *vulgare* crosses, Peterson[3] observed that although the susceptibility of the *durum* parent was carried over to most of the lines, a few lines showed a high degree of resistance to kernel smudge.

The incidence of kernel smudge in Western Canada varies greatly from season to season, and from district to district. Broadly speaking, it is always considerably higher in Manitoba than in Saskatchewan, and higher in Saskatchewan than in Alberta. In certain years, wheat losses from this disease, owing to the lowering of the commercial grade, reach appreciable proportions, particularly in Manitoba. Of 1000 cars each of durum and hard red spring wheat from different districts in Manitoba that were inspected at Winnipeg in 1940, 14.0 and 7.6%, respectively, contained noticeable amounts of kernel smudge, a large proportion of which was degraded for "black point".

Studies to determine the relative susceptibility of wheat varieties to kernel smudge were continued at Winnipeg in the years 1935–42, inclusive. During this period, certain standard varieties and new productions of durum and spring wheat were grown at several stations in Western Canada and their reactions to kernel smudge determined. In addition, during the 5 years 1938–42, plating tests were made of a large number of seed samples of wheat from different farms in Manitoba to determine the relative resistance of certain spring wheat varieties to internal kernel infection by *Alternaria* spp. and *Helminthosporium sativum*, the fungi chiefly associated with wheat seed discolorations in Western Canada. An account of these field studies and plating tests is given in this paper. A preliminary report on the subject has already been made (5).

EXPERIMENTAL RESULTS

Relative Susceptibility of Wheat Varieties to Kernel Smudge

In this investigation, the percentage of discoloured kernels in the threshed grain was the criterion used to compare the susceptibility of wheat varieties to kernel smudge. At least three 100-kernel lots were selected at random from the grain sample of each variety, and the number of smudged kernels in each lot was counted. The average of these counts gave the percentage of kernel smudge for that variety. In passing, it should be mentioned that a statistical study of different sampling and counting methods revealed that the precision of a kernel smudge count was not increased when more than three 100-kernel lots from each grain sample was used. All examinations of grain samples for kernel smudge were made with the unaided eye, under uniform, artificial light conditions, the examination of any given varietal test being made by one investigator. Thus, the disease data were obtained by uniform procedure, and are believed to give an accurate measure of varietal susceptibility to kernel smudge.

During the 7 years 1929–35, and in 1938, 1939, and 1940, a number of varieties belonging to each of the wheat groups *Triticum durum* and *T. vulgare* were tested for their reactions to kernel smudge. The varieties studied from 1929 to 1935 were grown at Winnipeg, Manitoba, while those

[3] Unpublished data of Dr. R. F. Peterson, Cereal Division, Dominion Rust Research Laboratory, Winnipeg, Man.

tested in 1938, 1939, and 1940 were grown at different stations, 3 in Manitoba and 2 in Saskatchewan. A summary of the kernel smudge data obtained is given in Tables 1 and 2.

TABLE 1.—PERCENTAGE OF KERNEL SMUDGE IN THE THRESHED GRAIN SAMPLES OF 3 DURUM AND 3 HARD RED SPRING WHEAT VARIETIES GROWN AT WINNIPEG, MANITOBA, IN THE 7 YEARS 1929–35

Variety	1929	1930	1931	1932	1933	1934	1935	Average (1929–35)
	%	%	%	%	%	%	%	%
Triticum durum								
Pentad	0.8	16.8	21.7	37.3	40.7	63.7	93.6	39.2
Acme	1.3	22.2	11.0	42.8	30.8	69.0	65.3	34.6
Mindum	2,6	11.5	15.7	33.4	39.3	24.2	55.0	26.0
Average	1.6	16.8	16.1	37.8	36.9	51.6	71.3	33.2
Triticum vulgare								
Marquis	0.4	4.1	2.6	3.6	0.7	9.3	10.8	4.5
Ceres	0.0	1.5	0.0	1.8	1.8	6.0	5.3	2.3
Reward	0.0	2.3	0.2	2.6	0.7	5.1	4.0	2.1
Average	0.1	2.6	0.9	2.7	1.1	6.8	6.7	3.0

TABLE 2.—MEAN PERCENTAGE OF KERNEL SMUDGE IN THE GRAIN SAMPLES OF 7 DURUM AND 7 HARD RED SPRING WHEAT VARIETIES GROWN AT STATIONS IN MANITOBA AND SASKATCHEWAN IN 1938, 1939, AND 1940

Variety[1]	R.L. No.[2]	1938	1939	1940	Average (1938–40)
		Number of test stations[3]			
		3	5	5	
		%	%	%	%
Triticum durum					
Iumillo × Mindum	1317	26.5	2.7	9.1	12.8
Iumillo × Mindum	1183	24.5	1.2	9.6	11.8
Mindum × Pentad	1245	17.3	0.7	1.9	6.6
Kubanka	1302	12.3	1.1	5.0	6.1
Pelissier	1303	11.1	1.2	4.5	5.6
Arnautka	570	8.2	1.3	4.0	4.5
Mindum	1344	9.2	1.0	2.5	4.2
Average	—	15.6	1.3	5.2	7.4
Triticum vulgare					
Apex	309	7.6	0.6	7.1	5.1
Thatcher	501	6.0	0.4	4.0	3.5
Renown	131	4.2	0.0	0.4	1.5
Marquis	1	0.0	0.0	2.6	0.8
Regent	135	2.2	0.0	0.4	0.8
Red Bobs	1827	1.2	0.0	1.0	0.7
Garnet	5	0.0	0.0	0.0	0.0
Average	—	3.0	0.1	2.2	1.8

[1] Varieties arranged according to the percentage of kernels affected by kernel smudge.
[2] Rust Laboratory Number, Cereal Division, Dominion Rust Research Laboratory, Winnipeg, Man.
[3] The varieties were grown at 3 stations in Manitoba in 1938, and at 3 in Manitoba and 2 in Saskatchewan in 1939 and 1940.

It is evident from the data in Tables 1 and 2 that wheat varieties differ markedly in their susceptibility to kernel smudge, and that, in general, durum wheats are more susceptible than are hard red spring wheats. The behaviour of the varieties was quite constant for different stations and years. The results in Tables 1 and 2 indicate that, in the development of seed discolorations in wheat, the variety of wheat involved is a factor of considerable importance.

To obtain more information concerning the relative susceptibility to kernel smudge of durum and hard red spring wheats, an examination was made of the car lot inspection records of the Western Grain Inspection Division, Department of Trade and Commerce, Winnipeg, Manitoba, for the crop years 1939–42, inclusive. The data obtained (Table 3) showed that in each of the 4 years 1939 to 1942, a higher percentage of the cars of durum wheat grown in Western Canada and inspected at Winnipeg contained kernel smudge than did those of hard red spring wheat. In 1940 and 1941 the losses from this disease in durum wheat, owing to the lowering of the commercial grade, reached appreciable proportions, particularly in Manitoba.

TABLE 3.—PREVALENCE OF KERNEL SMUDGE IN CAR LOTS OF DURUM AND HARD RED SPRING WHEAT PRODUCED IN WESTERN CANADA AND INSPECTED AT WINNIPEG IN 1939, 1940, 1941, AND 1942

Crop	Class of wheat	Number of cars inspected[1]	Percentage of cars with kernel smudge
		No.	%
1939	Durum	3,631	0.3
	Hard Red Spring	103,250	0.0
1940	Durum	447	14.0
	Hard Red Spring	24,498	3.8
1941	Durum	202	5.0
	Hard Red Spring	15,397	1.4
1942	Durum	934	2.7
	Hard Red Spring	15,644	0.1

[1] Cars inspected by Western Grain Inspection Division, Department of Trade and Commerce, Winnipeg, Man., from August 1 to October 31.

Since 1935 there has been, in respect to the varieties and the extent to which they are grown, a remarkable change in the wheat crop of Western Canada. In 1935, for instance, the acreage occupied by durum wheat in Manitoba was 39% of the total wheat acreage; whereas in 1942, it was only 5%. Furthermore, certain rust susceptible varieties of hard red spring wheat, such as Marquis and Reward, have virtually disappeared from Manitoba and southern and east central Saskatchewan. As a matter of fact, the introduction of rust resistant varieties has made such rapid progress in these areas that in 1941 and 1942, four varieties, Thatcher, Apex, Renown and Regent, occupied more than 90% of the wheat acreage in Manitoba and approximately 80% in Saskatchewan (9). In view of

this condition, information concerning the relative susceptibility to kernel smudge of the varieties of spring wheat now commonly-grown in Western Canada is of particular interest.

Data on the reactions to kernel smudge of 6 standard spring wheat varieties, including the stem rust resistant varieties, Thatcher, Apex, Renown, and Regent, were obtained in the 8 years 1935–42. These varieties were grown each year in co-operative tests conducted by the Subcommittee on Plant Breeding[4] at from 5 to 6 stations in Manitoba, from 3 to 7 in Saskatchewan, and from 3 to 6 in Alberta. A summary of the kernel smudge data is given in Table 4.

TABLE 4.—MEAN PERCENTAGE OF KERNEL SMUDGE IN THE THRESHED GRAIN SAMPLES OF CERTAIN STANDARD VARIETIES OF HARD RED SPRING WHEAT GROWN AT SEVERAL STATIONS IN WESTERN CANADA IN THE 8 YEARS 1935–42

Variety[1]	1935 (13)[2]	1936 (11)	1937 (12)	1938 (14)	1939 (17)	1940 (17)	1941 (15)	1942 (14)	Average (1935–42)
	%	%	%	%	%	%	%	%	%
Apex	4.8	0.4	8.2	4.0	1.8	3.5	7.2	2.6	4.1
Thatcher	2.4	0.2	5.1	2.3	0.5	2.1	3.0	1.2	2.1
Marquis	2.4	0.0	1.9	1.2	0.1	1.3	1.5	1.1	1.2
Renown	2.0	0.1	1.9	2.1	0.1	0.5	0.4	1.2	1.0
Regent	2.0	0.1	1.9	1.7	0.0	0.2	0.5	1.1	0.8
Garnet	0.0	0.0	0.0	Tr.	0.0	0.0	Tr.	0.1	Tr.
Average	2.3	0.1	3.2	1.9	0.4	1.3	2.1	1.2	—

Tr. = Trace of kernel smudge (less than 0.1%).
[1] Varieties arranged according to the percentage of kernels affected by kernel smudge.
[2] Number of stations in Western Canada at which the varieties were grown.

Table 4 gives the average annual kernel smudge percentages for all stations at which the varieties were grown. These data show that, each year from 1935 to 1942, Apex was more susceptible to kernel smudge than was any of the other varieties tested. Garnet, an early maturing variety, was the most resistant. Of the stem rust resistant varieties tested, Renown and Regent were consistently more resistant than were Apex and Thatcher. Although the varietal reactions to this disease were quite constant at the different stations and for the 8 years, the resistant variety Garnet, and the susceptible variety Apex, showed less tendency to vary between stations or between years than did the moderately susceptible or moderately resistant varieties.

A special variability study of susceptibility to kernel smudge was made in 1942 with 4 pure lines from reciprocal crosses between Thatcher and Regent. These were grown, along with certain standard varieties at 5 stations in each of the Prairie Provinces. Grain samples of each line and variety, obtained from each of the 15 stations, were examined for the presence of discoloured kernels. The results of this study are summarized in Table 5.

[4] Associate Committee on Field Crop Diseases (Western Section), National Research Council and Dominion Department of Agriculture, Canada.

TABLE 5.—MEAN PERCENTAGE OF KERNEL SMUDGE IN THE THRESHED GRAIN SAMPLES OF CERTAIN STANDARD VARIETIES AND PURE LINES FROM CROSSES BETWEEN THATCHER AND REGENT, GROWN AT 5 STATIONS IN EACH OF THE PROVINCES, MANITOBA, SASKATCHEWAN, AND ALBERTA, IN 1942

Variety or line[1]	R.L. No.[2]	Manitoba	Saskatchewan	Alberta	Average (15 stations)
		%	%	%	%
Thatcher × Regent	2012	14.3	6.5	5.5	8.8
Regent × Thatcher	2038	5.7	2.8	2.4	3.6
Apex	1342	4.3	1.4	1.1	2.3
Thatcher × Regent	2027	3.6	1.0	0.8	1.8
Regent	975.6	2.7	0.8	0.6	1.4
Thatcher × Regent	2041	2.8	0.5	0.5	1.3
Thatcher	1945	1.6	0.4	0.5	0.8
Garnet	15	0.0	0.0	0.3	0.1
Average	—	4.4	1.7	1.5	—

[1] Varieties arranged according to the percentage of kernels affected by kernel smudge.
[2] Rust Laboratory Number, Cereal Division, Dominion Rust Research Laboratory, Winnipeg, Man.

The data in Table 5 show that pure lines from crosses between Thatcher and Regent differed appreciably in their reactions to kernel smudge. Of those tested, R.L. 2012 was highly susceptible to the disease, whereas R.L. 2041 showed considerable resistance to it. Data for individual stations showed that significant differences existed between the different standard varieties and lines in their reaction to kernel smudge, and that the comparative varietal differences were quite constant at the 15 widely separated stations.

In 1942, a severe epidemic of leaf rust (*Puccinia graminis* Erikss.) occurred in Western Canada. In consequence, the incidence of kernel smudge was lower in the leaf rust susceptible variety Thatcher than in Regent, a variety possessing considerable resistance to leaf rust. As the results in Table 5 show, in 1942, the incidence of kernel smudge was considerably higher in Manitoba than in Saskatchewan and Alberta.

RELATIVE SUSCEPTIBILITY OF WHEAT TO KERNEL INFECTION BY SMUDGE-PRODUCING FUNGI

With the object of determining the presence and prevalence of smudge-producing fungi in the kernels, a large number of farm samples of Apex, Thatcher, Renown, and Regent seed from the 1938, 1939, 1940, 1941, and 1942 crops in Manitoba were examined for kernel smudge and subjected to a plate test. The percentage of kernel smudge in each sample was determined by an examination of three 100-kernel lots selected at random from each seed sample. To determine the internal fungous flora of the seed, 100 surface sterilized kernels of each sample were plated out on potato dextrose agar in Petri dishes. The plating methods used in other cereal seed studies were employed (7). The results of the plate tests and kernel smudge determinations are summarized in Table 6.

TABLE 6.—MEAN PERCENTAGE OF KERNELS INFECTED WITH *Alternaria* SPP., *Helminthosporium sativum*, AND OTHER FUNGI, AND EXHIBITING KERNEL SMUDGE, IN GRAIN SAMPLES OF APEX, THATCHER, RENOWN, AND REGENT WHEAT PRODUCED IN MANITOBA IN THE 5 YEARS 1938–42

Year and variety	Number of samples tested[1]	Mean percentage of kernels infected with:				Mean percentage of kernels smudged
		Alternaria spp.	*Helminthosporium sativum*	Other fungi[2]	Fungus-free seeds	
	No.	%	%	%	%	%
1938						
Thatcher	44	80.3	4.3	1.4	15.2	6.7
Renown	23	76.2	3.6	2.9	18.5	2.2
1939						
Apex	4	66.5	1.8	8.3	25.0	1.6
Thatcher	123	62.5	2.8	3.8	31.9	1.2
Renown	104	52.6	1.7	6.1	40.1	0.2
Regent	21	48.5	2.2	6.9	44.2	0.2
1940						
Apex	5	76.4	3.6	4.6	19.2	7.3
Thatcher	189	76.1	3.1	2.7	19.8	5.7
Renown	132	70.1	2.9	6.1	24.8	1.1
Regent	55	59.8	2.7	6.9	35.1	1.0
1941						
Apex	4	79.0	6.2	4.0	14.2	4.9
Thatcher	223	79.8	6.9	4.3	13.7	3.5
Renown	88	74.5	5.1	6.3	17.4	2.5
Regent	64	65.7	5.6	6.8	24.5	2.4
1942						
Thatcher	53	79.0	5.4	3.4	13.9	0.7
Renown	27	77.8	4.4	4.4	15.9	1.3
Regent	41	77.4	4.1	3.7	16.0	2.4

[1] One hundred seeds of each sample were surface sterilized and cultured on potato dextrose agar in Petri dishes.

[2] Chiefly fungi belonging to the genera *Nigrospora*, *Fusarium*, *Curvularia*, *Hormodendrum*, *Epicoccum*, *Septoria*, *Macrosporium*, and *Penicillium*.

The plate test results in Table 6 show that there were marked differences between varieties in their susceptibility to internal seed infection by species of *Alternaria* and *Helminthosporium sativum*, the fungi commonly associated with kernel smudge. Annually, from 1939 to 1942, the kernels of Apex and Thatcher were somewhat more severely infected with these fungi than were the kernels of Renown and Regent. In all years, more fungus-free kernels were found in Regent than in Renown, and considerably more than in Thatcher. On the other hand, a visual examination of the grain samples for discoloured kernels showed that Apex and Thatcher wheat seed produced in Manitoba in 1939, 1940, and 1941 contained more kernel smudge than did Renown and Regent. The results in Table 9 substantiate those presented in Table 4 and indicate that Apex and Thatcher are more susceptible to this disease than are Renown and Regent.

In 1942, owing to the occurrence of a severe leaf rust epidemic in Manitoba, the incidence of kernel smudge was lower in Thatcher and Renown than in Regent. From the literature on the subject, it appears that severe attacks of leaf rust (*Puccinia triticina* Erikss.) result in an appreciable reduction in kernel size (8, 10), and that discolorations typical of kernel smudge are less likely to be found in small shrunken kernels than in large, plump ones (7). Goulden (4), studying the relation between the amount of kernel smudge in a wheat variety and its susceptibility to stem rust (*Puccinia graminis Tritici* Erikss. and Henn.), found that the percentage of kernel smudge in the crop was significantly, but negatively, correlated with degree of infection by stem rust.

DISCUSSION

The results of the present investigation show that varieties of spring wheat differ appreciably in their reaction to kernel smudge, and that varieties and selections of wheat with considerable resistance to the disease are available. Thus, even if it is impossible to obtain varieties that possess complete resistance, it should be practicable to breed wheats that have a high degree of resistance to kernel smudge. Undoubtedly, the growing of resistant varieties is the most practical method of controlling this disease of wheat, barley and rye.

During the 5 years 1938–42, a total of 1200 samples of wheat seed obtained from different districts in Manitoba were examined for kernel smudge and for the presence of fungi in the seed. These studies showed that only a small proportion of the kernels infected with species of *Alternaria* and *Helminthosporium sativum* exhibited discolorations typical of kernel smudge. Thus, it would seem that, although favourable conditions for infection of wheat kernels occur in Manitoba, the environmental conditions that prevail in that province subsequent to infection are usually not favourable for the development of kernel smudge.

In the period under review, field observations have shown that, if the climatic conditions are congenial to the rapid ripening and harvesting of a wheat crop, the incidence of kernel smudge is low; but, if warm, humid weather, with heavy dews, occurs during the later stages of plant growth, the incidence is high. These observations confirm the work of Machacek and Greaney (7) who consider that, in addition to abundance of airborne inoculum and stage of host maturity, the occurrence of favourable climatic conditions, particularly during the later stages of plant growth, is one of the main factors responsible for the severity of kernel smudge in wheat. The results of the present investigation indicate that an important factor affecting the prevalence of this disease in Western Canada is the variety of wheat grown.

SUMMARY

A number of wheat varieties were tested for their susceptibility to kernel smudge caused by species of *Alternaria* and *Helminthosporium sativum* at several stations in Western Canada from 1935 to 1942. In general, varieties of *Triticum durum* were considerably more susceptible to kernel smudge than were those of *T. vulgare*. The commonly grown varieties of

hard red spring wheat tested ranked in order of susceptibility to kernel smudge as follows: Apex, Thatcher, Marquis, Renown, Regent, and Garnet. Garnet, an early maturing variety, was highly resistant to the disease. Of the stem rust resistant varieties tested, Apex and Thatcher proved to be more susceptible than Renown and Regent.

The results of extensive plating tests with a large number of Manitoba samples of Apex, Thatcher, Renown, and Regent seed of the 1939, 1940, 1941, and 1942 crops, showed that the varieties Apex and Thatcher were slightly more susceptible to internal seed infection by *Alternaria* spp. and *H. sativum* than were Renown and Regent. In all years, the percentage of kernels infected internally with these fungi was appreciably higher than the percentage of kernels exhibiting typical external symptoms of smudge. However, it was found that, in years when leaf rust was not a complicating factor, the degree of internal kernel infection was always positively associated with the incidence of kernel smudge in the threshed grain.

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DETERMINATION OF FLESHING CHARACTERISTICS IN MARKET POULTRY[1]

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Attractive appearance unquestionably contributes to the sales appeal of dressed poultry carcasses. Grading regulations therefore endeavour to visualize the disposition of fleshing and the degree of fatness and finish which shall be characteristic of each grade as well as the elimination of blemishes such as tears, pin feathers, crooked keels and breast blisters. While the quantitative recognition of defects does not offer any serious obstacles, the opposite is the case with fleshing and fatness. In commercial grading practice the latter qualities are frankly admitted to be evaluated by subjective impressions. Since these are affected by idiosyncrasies peculiar to the individual grader and by variations in judgment with time and antecedent experience, doubt is raised about their usefulness as adequate tools for estimation of the characters involved. In this connection fleshing is of the greater importance as it is the expression of a genetic factor reacting to given environments at all ages throughout life. Fatness on the other hand is mainly dependent on the biological response of the organism to feeding practice. The aim of the breeder therefore is, in the first place, to learn how to measure muscular development and its attractive disposition on the skeleton of the living bird, and thereafter to find whether statistically significant familial segregation occurs which will render progeny testing for this character feasible.

In an endeavour to show the influence of sires on fleshing and conformation characteristics in their sons Maw and Maw (17) presented X-ray photographs of the progeny of three males. While this pictorial material still left determination of fleshing type to individual observation some concrete data were presented at this time. It was found that the three sires used in this study significantly influenced length of back, keel and shank in their progeny, but had little or no effect on body weight as well as breadth and depth of body. Maw and Maw (18) also found that increase in body length and depth as well as length of leg was inversely correlated to percentage of edible meat, while length of keel and circumference of tibia were positively associated with percentage edible portion. However, none of their correlations seem high enough to have any practical importance. Substantial progress was made when Jaap (7, 8, 9, 10) and Jaap and Penquite (11) devised their method for measuring fleshing by dividing shank length by the cube root of body weight. Jaap found that roundness of breast has greater influence on the monetary value of a bird than any other characteristic. However, he discards determination of breast contour owing to the large experimental error involved in securing

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these measurements on the live birds and states that the relationship of shank length to cube root of body weight proved much superior for use in breeding studies. He acknowledges the poor agreement between results obtained by his fleshing index and by commercial grading. Scott (20) emphasized the disagreement obtained by visual grading and by Jaap's index. Lerner (12, 13) maintained that Jaap's formula is inadequate in that it assumes constancy of the α power in Huxley's (5, 6) relative growth equation and thus throws all the weight of differentiation on the b value. In effect this amounts to the arbitrary selection of a constant slope for all regression curves, and Lumar *et al.* (16) recently mentioned that in biological series such as these the α and b values generally bear an inverse relationship to one another with the result that all the regression curves have a tendency to cross over inside an approximately common area. Dolecek *et al.* (1) devised a technique for grading dressed roasters using several physical measurements for determination of fatness and outward form. Their final score obtained on dressed carcasses is doubtless more nearly correct than routine market grading based on personal intuition can hope to be. However, determination of body shape on living specimens, where softness of tissues and respiratory movement make end points uncertain, will argue against adoption of Dolecek's technique for breeding purposes. It was in fact this uncertainty which led both Jaap and this author to discard such measurements as unreliable criteria for the shape of living birds.

These problems have been studied in this laboratory for several years and since some measure of finality has been arrived at it seems appropriate to summarize results at this time.

EXPERIMENTAL

Results of Initial Tests

It seemed reasonable to assume that some quantitative measure of fleshing would be correlated to grade. The dressed weights of 175 birds of various breeds and sexes were therefore correlated to numerical values assigned to their market grades. The net coefficient of correlation was found to be $+0.348$.

Next, the percentage edible portion from these carcasses as transformed to degrees of an angle by Fisher's (2) formula was analysed by variance. When degrees of freedom and sums of squares were pooled for the various classes the F value exceeded the 0.01 point, but even so no significant difference was found between the numerically most important A and B grades.

When grade values were correlated to the absolute weight of edible portion the net correlation was $+ 0.503$. The regression was 215 gm. between succeeding grades, hence the average difference of edible portion between carcasses of the highest and lowest of the four grades would be 645 gm. However, in view of the relative uncertainty of determination implied by a moderate correlation commercial grading could not be accepted as a reliable measure of the quantity of meat on a carcass. Furthermore when the main object is to evaluate market qualifications from quantitative estimates of fleshing in the living bird the problem becomes somewhat more involved.

Subsequent Experiments

During earlier work it had been found that roughly from 60 to 80% of the dressed carcass weight constituted the edible portion. It was therefore argued that if two birds were of identical skeletal size the heavier one of the two would probably be possessed of the largest muscular mass and so, it was reasoned at the time, be the plumper one of the two. The immediate object would therefore seem to be a determinaion of the deviations of observed from expected body weight relative to skeletal size, the magnitudes of these deviations to decide the relative merits of the individual birds. The allometric law $x = by^{\alpha}$ would serve this purpose when weight was treated as the dependent and skeletal size as the independent variable.

For the purpose of testing this hypothesis 50 Barred Rock and 66 White Leghorn cockerels were killed at 29 weeks of age. For both breeds these birds constituted all surviving male progeny from 11 matings to 5 sires with at least 2 matings to each sire. All birds were weighed after being starved overnight and various skeletal measurements secured. They were then killed, dressed, graded and stored at 10° F. below zero. On removal from storage a transverse section about 5 to 8 mm. thick was sawed out of the frozen carcass immediately forward of the anterior point of the keel and a careful tracing made of the posterior face of this section. The pectoralis major, secundus and tertius were then freed at their insertions on the humerus and dissected out and weighed. The muscles of the posterior extremities from the sartorius to the semitendinosus were likewise freed at their origin on the ilium, sacrum and ischium, dissected out and weighed to the nearest 0.1 of a gram. These muscles represent all of the edible portion except the skin and muscles on neck and wings. Total edible portion was determined by difference between the weight of the dressed carcass and the combined weights of head, feet, offal and bones.

Indices of Relative Roundness of Breast Muscular Weight and Skeletal Size

The chosen transverse section through the birds presents the maximum width and roundness of the breast at the point where the full depth of the sternum is likewise manifest. The relative roundness of these sections was repeatedly found to coincide almost perfectly with the rank numbers of carcasses that had been aligned according to attractiveness of fleshing. Throughout this work such sections have therefore been used as the most critical record obtainable of attractive conformation.

In order to justify body weight as an index of muscular development the former was correlated to edible portion from all 116 birds. The net coefficient of correlation within breeds was +0.942 and starved live weight was therefore accepted as an index to weight of musculature.

On correlating the various skeletal measurements it was found that the length of all long bones bears a close relationship one to the other, their coefficients of correlation being of the order of +0.8. All other bones were found to be poorly correlated, and length of the long bones therefore determines body size more consistently than any other skeletal measurement. Moreover the length of one long bone will be a fair index of general size. The lengths of tibia and metatarsus are of all long bones the most easily secured in live specimens. On correlating the length of each bone

as measured on the live birds with its length when clean and air-dried the coefficients were found to be for tibiae +0.944 and for metatarsae +0.838. The mean error between expected and observed live measurements were for tibiae 0.93% and for metatarsae 1.51%. In our hands therefore, tibiae were measured slightly more accurately than metatarsae and hence were adopted as indices of skeletal size.

Determination of Relative Fleshing

Having justified the indices for muscular weight and skeletal size the regression of log body weight (x) on log tibia length (y) were secured for the two breeds as shown in Table 1.

Table 1.—Mean indices, log correlations and log regressions

	Mean body wt.	Mean tibia	Log r	Log regression equation
	gm.	mm.		
Barred Rock	3124.5	180.3	+0.340	$x = 1.06055 + 1.07904\ y$
White Leghorn	2126.2	157.3	+0.726	$x = -0.71778 + 1.84162\ y$

From the log regression equations, the expected body weight in actual numbers relative to the observed tibia length was calculated for each individual bird. The deviations between these and observed body weights which hereafter are referred to as "Fleshing Index" were secured and correlated to the combined actual weights of pectoral and leg muscles. The net correlation coefficient within tibia length classes of 2 mm. for Leghorns and 4 mm. for Rocks were +0.912 and +0.938 respectively. It is apparent that deviations of expected from observed body weights as secured from the size weight regression estimate relative fleshing with precision.

Relationship of Relative Fleshing to Plumpness

The tracings of frozen sections were ranged in descending order according to the value of their fleshing indices. This array revealed that relative fleshing is not necessarily a good criterion of plumpness. Thus a very well fleshed carcass might often be of quite poor appearance on account of excessive depth of carcass. On the other hand mediocre relative fleshing might be coupled with plump appearance provided the carcass was sufficiently shallow. The two birds, sections of which are shown in Figure 1, had approximately the same body weights and tibia lengths and consequently very nearly identical fleshing indices. In spite of this the two carcasses differed radically in plumpness and grading appeal.

This was accounted for by the difference in dorso-ventral depth which was 126 mm. in one and 144 mm. in the other. This difference in anatomical conformation of the thoracic skeleton necessitated that almost identical volumes of pectoral muscle in one bird be laid down in thin, broad bundles giving it a slabsided appearance, and in the other deposited in thick rounded muscles giving it a plump appearance.

Since there is small virtue in segregating large fleshing volume if its attractive distribution is neglected, it therefore becomes necessary to take account of depth of body as well as of fleshing index. This may be accomplished by obtaining the deviations of observed from expected fleshing indices relative to body depth or by securing the deviation of observed from expected body weight relative to the geometric mean of tibia length and body depth. These values, which have been termed "Grading Indices" placed the sections of the birds in their proper order of merit as regards smooth roundness of contour with very few errors. The grading index thus is a numerical expression of attractive appearance and is arrived at by referring body weight to two important indices of body

FIGURE 1. Transverse sections immediately forward of anterior point of keel. *Left*—Barred Plymouth Rock cockerel No. 592. Starved live body weight 3418 gm., length of tibia 183 mm., fleshing index 242 gm. body depth 126 mm. *Right*—Barred Plymouth Rock cockerel No. 306. Starved live body weight 3468 gm., length of tibia 185 mm., fleshing index 255 gm., body depth 144 mm. Reduced $\frac{1}{2}$ diameter of natural size.

size namely, length of tibia and depth of thoracic skeleton. However, the errors that do occur in determination of body shape by the grading index, although few may be quite pronounced. These errors are due mainly to excessive individual deviations from mean keel length. An extraordinarily long keel may detract from the round appearance of a breast whereas a very short keel may enhance it. Since the few radical departures from the relatively normal keel lengths which are capable of introducing these disturbances are entirely unpredictable it will be found advisable in breeding operations to consider superior fleshing index and moderate to small body depth separately. Desirable families will then be those that excel in both characters.

Breeding for Improved Market Type

The two samples of 50 Rocks and 66 Leghorns served to test the usefulness of this scheme. The records of each breed were separated in their 11 full brother groups and the relationship between fleshing indices and

total weight of pectoral and leg muscles analysed by covariance. The net correlation coefficients within brother groups of Rocks and Leghorns respectively were +0.825 and +0.801 even when all sizes of brothers were pooled. However, the variance analysis of fleshing indices yielded the valuable information that whereas the Rocks showed highly significant difference between full brother groups this was far from being the case for the Leghorns. Furthermore, similar analyses of body depth showed highly significant differences between the full brother groups of Rocks and none for the Leghorns. In these two samples, segregation of superior market type would therefore have been very promising in the Rocks and quite purposeless in the Leghorns.

Commercial Grading in the Light of Concrete Determinations of Fleshing and Fat

The success or failure of any effort directed towards the breeding of improved market type must ultimately be judged by its impact on commercial grading results. It therefore becomes important to analyse the reliability of routine commercial grading.

Canadian grading standards specify separately the disposition of flesh and fat for each grade and grading practice endeavours to assay these factors independently. The official Canadian "Regulations Respecting the Grading and Marketing of Dressed Poultry" (19) which were applied in these tests by officials of the Dominion Marketing Service contain specifications for fleshing and fatness as set forth in Table 2.

TABLE 2.—OFFICIAL GRADING REQUIREMENTS

Grade	Fleshing in relation to length and depth of body	Fat over breast back hips and pin bones
"Special"	Well fleshed, breast full	Well covered
"A"	Relatively well fleshed slightly prominent keel will not disqualify	Well covered
"B"	Reasonably well fleshed insufficient to meet grade A requirements	Sufficient to prevent a dark red appearance
"C"	Fairly well fleshed	

Although fat is not important in a breeding scheme its value as a preventive against dehydration during storage and cooking, as a generally accepted aid to finish and bloom, and as a producer of flavour in roasting secures for it important consideration in market grading. Gutteridge (3, 4) has shown that fat is laid down in the various depots in an orderly manner and approximately gram for gram subcutaneously and abdominally. Also that samples of the pectoral feathertracts yield practically perfect indices to the general fatness of carcasses.

For the purpose of determining the relative accuracy of market grading a small sample of 23 Barred Rocks was secured. The dressing and sampling procedure as outlined above was applied with the addition that a transverse section of the pectoral feather tract was taken for fat determination. In Table 3 is presented the manner in which commercial grading segregated the actual percentages of fat, as expressed in degrees of an angle.

TABLE 3.—DISTRIBUTION OF FATNESS BY VISUAL GRADING

Grades	Fat Determinations										
Special and A	50.0	48.8	48.4	46.2	45.0	44.5	42.9	39.8	38.1		
B	44.5	44.4	41.9	41.8	41.4	39.1	38.2	36.7	36.6	30.0	29.6

3 Samples lost.

The mean for the whole distribution is 41.39 ± 5.56 and although the statistical difference between the two grades therefore is of unquestionable significance, considerable overlapping does occur. Let it be assumed that the mean value had acted as the point of segregation for the fatness characteristic of the higher grade from that of the lower one. It will then be seen that the smallest value which commercial grading deemed worthy of the superior grading was not quite one standard error lower than the mean, and the highest value referred to the inferior grade was higher than the mean by the same amount. It may therefore be estimated that approximately the 50% of all determinations which are grouped closest to the boundary between the grades are liable to misplacement by routine grading. Consequently, it is only pronounced fatness or leanness respectively which visual observation is able to appreciate with certainty.

When grading practice attempts to estimate fleshing separately the breast is considered exclusively. Moreover, it is the attractive appearance of the breast and not its quantitative fleshing which is being estimated. The latter has only importance as the raw material from which roundness of breast may be formed.

At the time when the carcasses were commercially graded the operator also placed them in alignment from the most attractive to the poorest in order of merit.

In Table 4 is presented the manner in which commercial grading distributed the alignment numbers to the various grades. Below these numbers are shown the calculated grading indices for each carcass. Index values which did not truly represent the appearance of the birds as judged by the cross-sections are marked by an asterisk.

TABLE 4.—DISTRIBUTION OF ALIGNMENT NUMBERS AND INDEX VALUES TO COMMERCIAL GRADES

Grade	Alignment numbers and indices											
Special	1 93*	2 490	3 376	5 253	8 174	9 93*	11 151	17 210*				
A	4 300	6 288	7 177	10 124	12 70	13 16	14 62	15 16 134*−76		18 11	19 −132	20 1*
B	21 −173		Grade C			22 −568		No grade			23 −925	

It is apparent that commercial grading was as unreliable in estimation of attractive appearance of fleshing as it had been in evaluating fatness since considerable overlapping occurred between the grades.

Commercial grading can therefore only be accepted with the reservation that all its decisions regarding borderline cases between grades, whether for fatness or for fleshing, are subject to error.

DISCUSSION

In the light of a great volume of published data to that effect, it is probably by now agreed that total body weight may be regarded as relatively unimportant to egg production. The most pertinent consideration of body weight is consequently its market value and its segregation into types may therefore proceed without complicating consideration of other factors.

At the present time practically all poultry flocks exhibit a wide variety of sizes and shapes and are accordingly degraded when brought to market. Breeding for improved market type therefore resolves itself into efforts towards elimination of the prevailing variation by segregating and standardizing families of uniformly good type within those breeds in which the precise fleshing index as well as thoracic depth show significant familial segregation.

Routine grading serves as an estimate of market value and will continue to be indispensable to commercial practice for reasons of speed and convenience in spite of the lack of precision inherent in this method. The native inexactitude is fundamental because such grading involved that each carcass must be evaluated separately without any but a mentally recorded standard, and the errors to which this led was shown by the discrepancies between commercial and alignment grading. In the latter method each specimen is compared to others and the order of merit thus arrived at agreed almost perfectly with a similar arrangement of the frozen cross sections. In fact, alignment grading is probably the nearest possible approach to faultless grading. However, alignment grading is for obvious reasons impracticable for commercial grading as well as for breeding purposes. Nevertheless the superior nature of alignment grading suggests that commercial grading might benefit by ready reference to pictorial borderline standards. At present the best that can be said for commercial grading is that about half of the birds which rightly belong in any one grade will be correctly graded while the others have an equal chance of being placed in one of the adjoining grades. In other words there is a strong tendency for good birds to get a high grading and for poor ones to be graded low, without the individual grades possessing the character of definite quality designations. Commercial grading can therefore not be accepted as a tool for segregating superior market type but it will over a period of time act as a sieve which will determine, albeit rather coarsely, whether the average quality of all meat stock improves or remain static.

Lloyd and Clandinen (15) and Lloyd (14) reported improvement in market conformation of two breeds obtained by the method of grading breeding birds for U, V, and I shape of the breast. When progress can be attained by such a relatively inexact technique it is safe to assume that breast shape is dependent on quite few genes for its expression. These authors rightly state that deep bodied birds are of low grade but incorrectly assume that slabsided birds carry little meat on the breast. The method which has been evolved and herein presented is capable of supplying precise quantitative determinations of relative volume of fleshing and thus giving numerically expressed measures of the material whereof roundness of breast may be created. When at the same time selection is practised for shallowness of torso attractive appearance cannot fail to be secured within a relatively short span of time since both characters show familial segregation.

SUMMARY

A technique has been evolved for accurate determination of relative fleshing from exact measurements on living birds.

This measure of fleshing, which has been termed Fleshing Index, is the deviation of actually observed from expected body weight relative to skeletal size as indicated by the length of tibia. It is obtained through the logarithmic regression of body weight on tibia length. That this index is an accurate measure of fleshing is shown by the fact that the calculated deviations are almost perfectly correlated to the actual weight of combined breast and leg muscles which were dissected off the carcasses.

However, a large volume of flesh which happens to be deposited on a carcass of excessive dorso-ventral depth through the thoracic region will produce a poor type. Inversely a good type may be the product of a moderate volume of flesh and a relative shallow body. Hence consideration of depth of torso must proceed simultaneously with determination of fleshing index when market type is considered.

Commercial grading has a pronounced tendency to award superior grading to high quality carcasses and inferior grade to poor ones. However, considerable overlapping occurs among specimens that approach the boundaries between grades. This is equally true for fleshing type and for fatness. Individual grades therefore lack the character of definite quality designations. Hence, routine market grading is unreliable as a basis for selection of breeding worth. Since fleshing indices and thoracic depth alike showed familial segregation in the Barred Rock breed these precise criteria of fleshing type may be used advantageously as progeny testing tools for market type in this breed.

ACKNOWLEDGMENTS

Sincere thanks are due to Mr. E. D. Bonyman for assistance in grading, to Dr. A. R. G. Emslie for fat determinations, and to Dr. J. W. Hopkins of the National Research Laboratories for helpful advice regarding biometrical analysis.

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STUDIES RELATING TO FERTILITY IN ALFALFA (*MEDICAGO SATIVA* L.)

II. TEMPERATURE EFFECT ON POLLEN TUBE GROWTH[1]

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It has long been realized that temperature has a profound effect on certain biological processes. The relationship of temperature to pollen tube growth has been studied for several plant species, but as far as is known, there is no published report of studies made on alfalfa. Therefore, during the summer of 1939, some tests were conducted to ascertain the responses of pollen tube growth to different temperatures.

LITERATURE REVIEW

Sandsten (6), using the pollen of apples and plums germinating on a cane sugar solution, obtained an increase in growth rate of the pollen tubes with an increase in temperature (86° to 93.2° F.).

Working with *Datura*, Buchholz and Blakeslee (4) found that within limits, the growth rate of pollen tubes increased as the temperature increased. They tested the tube growth in pistils, using a temperature range of 52° to 98.5° F. The growth rate increased steadily from 52° to 92° F., with a slight decline at 98.5° F.

Smith and Cochran (7) concluded that a temperature between 70° and 85° F. was optimum for pollen germination and tube growth in the tomato. Germination was poor at both 50° and 100° F.; and tube growth, while slow at both temperatures, was more limited and irregular at 100° F.

Cummings *et al.* (5) found that on 4/10N sucrose- and glucose-agar media, the tubes of pear pollen grew more rapidly at 80° than at 58° F. They also found that in the pistils, the growth rate of the tubes was less at 58° than at 80° F.

MATERIALS AND METHODS

Table 1 lists descriptive information for the 3 alfalfa plants used for this study. These 3 plants were among the ones collected and classified by Bolton (2), and were grown in an isolation screenhouse. All were classed as fertile and had an erect growth habit.

TABLE 1.—LIST OF PLANT MATERIAL

Plant designation	Strain and plant number	Varietal origin	Flower colour
4	I.31.9 (21–23)	Grimm	Light purple
5	S[1].32.32 (47–5)	Cossack	Bluish
6	I.28.18 (14–38)*	Grimm, Disco	Medium purple

* This plant is the same as I.28.18 (8-28), and designated as 8-28f by Bolton and Fryer (3).

[1] A portion of a thesis presented to the Committee on Graduate Studies, University of Alberta, in partial fulfilment of the requirements for the degree of Master of Science.

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Because of the difficulty of detecting the stained pollen tubes in the styles, all samples were collected one-half hour after the flowers were tripped so that the tubes could be readily stained and measured while still in the stigma.

The temperatures used for this experiment were obtained in various places, and these will be referred to as "stations" in the text.

A temperature of 50° F. was obtained in a large cooling chamber equipped with a refrigeration unit. Another "station" was established in the anteroom of the above mentioned cooling chamber and was held at a temperature of 70° F. A series of three temperature cabinets in the greenhouse was maintained at 70°, 80° and 90° F. For the temperature of 100° F., an incubation oven in the laboratory was employed.

The temperatures at these "stations" fluctuated somewhat, but during the half-hour periods when the tests were made, the temperature changes were very small. Temperatures recorded for the different "stations" were those registered at the time the tests were carried out.

Stem cuttings of the alfalfa plants in bottles of tap water were placed in the various "stations" at least 12 hours prior to the test period. Ten to 12 flowers were tripped on each cutting, and after one-half hour were removed from the temperature "stations" and treated in the following manner.

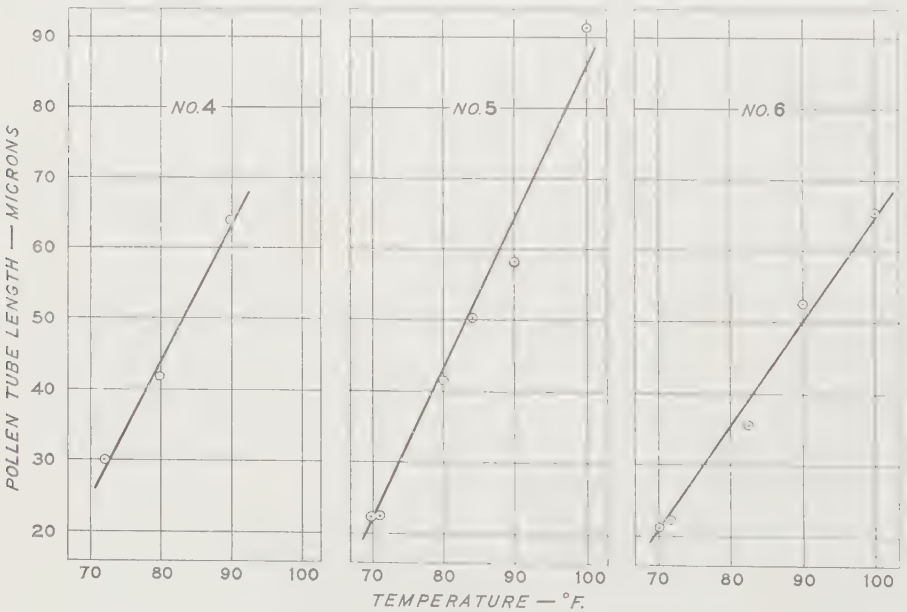

FIGURE 1. Temperature effect on pollen-tube growth during half-hour periods.

The pistil was dissected out from the surrounding floral parts, and the stigma and style removed in one piece by clipping with a pair of scissors. This portion was then placed on a microscope slide in a killing and staining solution, a cover-glass applied, and by pressure applied to the cover-glass the stigma was slightly crushed and spread.

The killing and staining solution was suggested by Armstrong and White (1). It consisted of lacto-phenol, to which was added a small amount of an acid fuchsin—light green stain. The stain was made up of 8 parts of 1% aqueous acid fuchsin and 2 parts of 1% light green in 95% alcohol.

Six stigmas were collected at each temperature for a single determination. Measurements of the pollen tubes were made with the aid of an ocular micrometer, at a magnification resulting from the use of a 4 mm. objective in combination with 10× oculars. Measurements were recorded as units of the micrometer scale and later changed to microns.

EXPERIMENTAL RESULTS

The results from the tests are presented in Table 2. These results are summarized in Table 3, and a graphic representation is to be seen in Figure 1.

In no case did the pollen germinate at 50° F. in the allotted half-hour period. A slight bulging at the germ pores was seen in most instances, but no real pollen tubes had been formed. At all other temperatures, germination appeared to be quite normal, though no counts were made.

TABLE 2.—TEMPERATURE EFFECT ON POLLEN TUBE GROWTH DURING HALF-HOUR PERIODS

Plant designation	Date	Temperature degrees F.	"Station"	Number of stigmas	Number of tubes measured	Mean length of tubes
						microns
4	28/7/39	72	Chamber	6	40	31.91 ± 1.283*
		80	Cabinet	6	29	40.46 ± 2.314
		90	Cabinet	5	32	68.11 ± 3.065
	29/7/39	72	Chamber	5	41	28.39 ± 1.182
		80	Cabinet	5	37	43.72 ± 2.335
		90	Cabinet	2	12	53.70 ± 6.166
5	1/8/39	50	Chamber	6	0	No germination
		70.5	Chamber	4	24	22.16 ± 1.122
		70	Cabinet	4	33	23.39 ± 1.501
		80	Cabinet	6	36	41.80 ± 2.321
		90	Cabinet	6	54	58.22 ± 2.653
	3/8/39	50	Chamber	6	0	No germination
		70	Chamber	6	43	20.85 ± 0.706
		70	Cabinet	4	33	22.66 ± 1.241
		84	Cabinet	3	22	50.71 ± 3.071
		90	Cabinet	2	5	58.37 ± 4.650
	4/8/39	100	Oven	5	38	91.84 ± 4.812
	5/8/39	100	Oven	3	22	91.06 ± 6.659
	4/8/39	50	Chamber	5	0	No germination
		71.6	Chamber	5	28	22.15 ± 1.148
		70	Cabinet	4	23	21.81 ± 1.450
		82.4	Cabinet	6	104	35.90 ± 1.305
		90	Cabinet	5	48	52.56 ± 2.873
		100	Oven	4	29	68.87 ± 4.845
	5/8/39	50	Chamber	4	0	No germination
		70	Cabinet	4	31	21.08 ± 0.857
		100	Oven	2	15	58.78 ± 3.710

* Standard Error of the mean.

The results indicate that there is a linear relationship between the length of the pollen tubes and the temperature, this relationship holding for temperatures from 70° to 100° F. for the half-hour period.

TABLE 3.—SUMMARY OF DATA ON TEMPERATURE EFFECT ON POLLEN TUBE GROWTH

Plant designation	Temperature degrees F.	measured Number of tubes	Mean* length of tubes (microns)
4	72	81	30.14
	80	66	42.28
	90	44	64.19
5	70	109	22.17
	70.5	24	22.17
	80	36	41.80
	84	22	50.71
	90	59	58.22
	100	60	91.55
6	70	53	21.80
	71.6	28	22.15
	82.4	104	35.89
	90	48	52.57
	100	44	65.43

* Weighted means derived from data in Table II.

An examination of the standard errors of the mean pollen-tube lengths (Table 2), would lead to one of two inferences. Firstly, that tube length is more variable as the mean length increases; or secondly, that growth rate differential is greater at the higher temperatures than at the lower temperatures. Neither of these inferences can be confirmed by reference to the data given. However, pollen-tube measurements made in another study, to be reported in a later paper, indicate that the variability in pollen-tube length increases with an increase in the mean length.

Microphotographs were made from the prepared material, and these are to be seen in Figures 2 and 3.

DISCUSSION

The results obtained in the aforementioned studies indicate that pollen tubes grow more rapidly as temperature increases. It must be remembered, however, that in the half-hour test period, two distinct processes occurred. These were germination and pollen-tube elongation. As has been shown by other workers for different plant species, the germination rate is affected by temperature, being more rapid at higher temperatures.

It is of interest to note the tube growth at 100° F. (Table 3 Figures 2 and 3), which appeared to be quite normal. At this same temperature Smith and Cochran (7) found the pollen-tube growth of tomato to be very poor; the length, even after 54 hours, not being as great as the length attained in 12 hours at temperatures of 70° and 85° F.

The plants tested in these experiments were classed as fertile, and each set pods quite freely on selfing. The reaction of the pollen tubes of poorer pod-setting plants to temperature is not known. It may be that the tubes of such plants behave in a somewhat different manner, thus accounting, in part, for the poorer pod- and seed-setting.

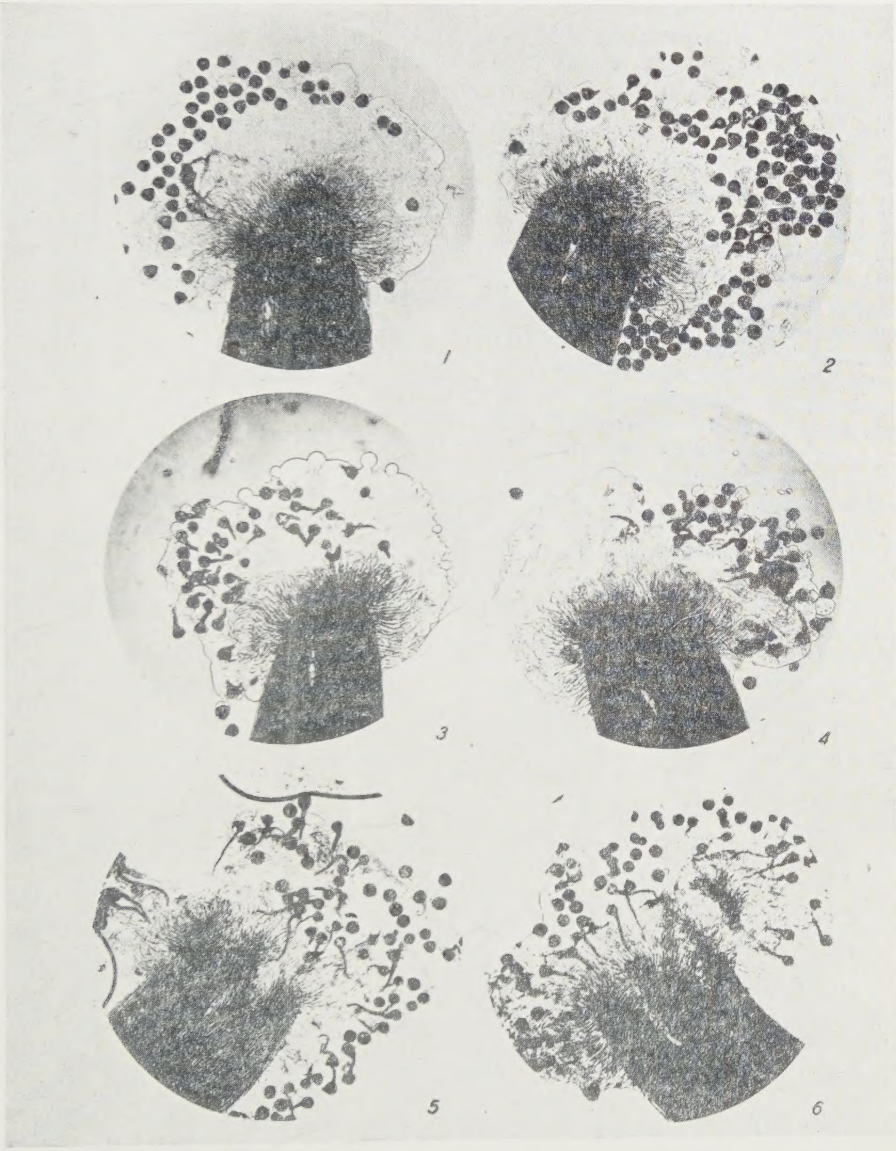

FIGURE 2. Pollen-tube growth of plant No. 5 during half-hour period. × 65. Grain with tube corresponding to mean length marked by a white cross.

Legend	Temperature	Station
1	50° F.	Chamber
2	70° F.	Chamber
3	70° F.	Cabinet
4	84° F.	Cabinet
5	90° F.	Cabinet
6	100° F.	Oven

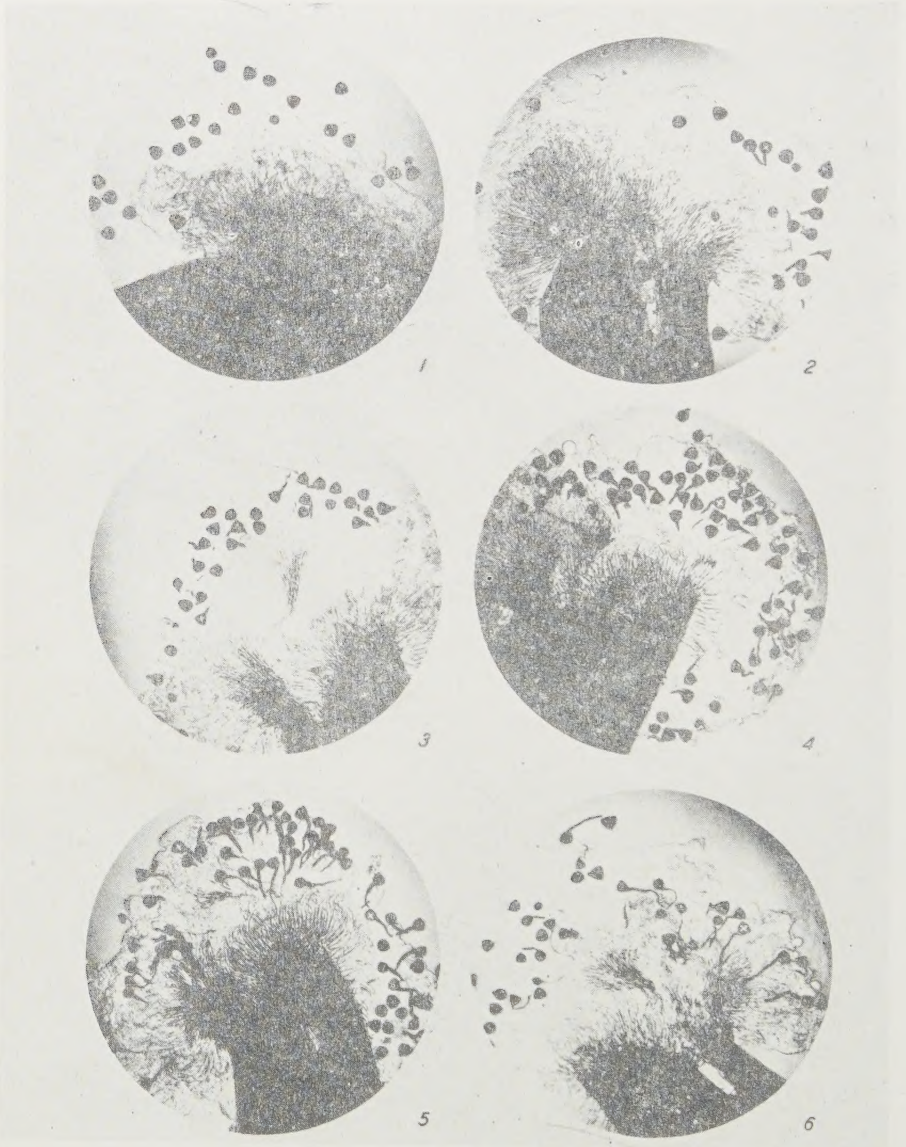

FIGURE 3. Pollen-tube growth of plant No. 6 during half-hour period. × 65. Grain with tube corresponding to mean length marked by a white cross.

Legend	Temperature	Station
1	50° F.	Chamber
2	70° F.	Cabinet
3	71.6° F.	Chamber
4	82.4° F.	Cabinet
5	90° F.	Cabinet
6	100° F.	Oven

SUMMARY

A linear relationship was found to exist between pollen-tube growth and temperature, the length increasing as the temperature increased from 70° to 100° F.

At 50° F. no germination occurred in one-half hour although a slight bulging at the germ pores of the pollen grains could be seen.

The pollen tubes formed at 100° F. were normal in appearance with no irregularities such as have been described for the pollen tubes of other plant species growing at this same temperature.

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BOOK REVIEW

THE BATTLE OF THE LAND. By N. Gangulee. Published by Lindsay Drummond, London, Eng. Price 6s.

The author, who was formerly Professor of Agriculture and Rural Economics in the University of Calcutta, India, and now is a Research Scholar at Rothamstead Experimental Station, has made an extensive study of the food production campaign in wartime Britain. Sir E. J. Russell in a foreword states that "As a trained agriculturist, Professor Gangulee is able to appraise at their full value the significance of these varied developments. He has searched the available records, and in order to avoid possibilities of error has quoted fully from them. His judgments are kindly, sympathetic and well balanced....".

This is a small book running to 135 pages, but it contains a large amount of information. Part I on the Campaign for Food Production, treats of the extension of arable farming, mechanization, land reclamation, maintenance of fertility, and the contribution of small holdings and allotments to food production. Part II discusses the Land Army and includes material on farm wages and housing. Part III on the Food Front includes statistics and discussions on arable crops, livestock farming, milk and milk products, and the problem of feeding the nation.

Illustrations include six pictorial diagrams, sixteen pages of photographs, and two page-size maps on land classification of England and Wales, and types of farming in England, Scotland and Wales. Appendices include a summary of the Land Fertility Scheme and the Agricultural Goods and Services Scheme, a Cost of Living Index to December, 1942, and an index of Retail Food Prices to December, 1942.

This is a useful publication for any one desiring a general summary of Britain's wartime agricultural production policies and their effect on British agriculture.

H. L. TRUEMAN.

ERRATUM

In the article entitled, "An estimate of loss in Manitoba from common root rot in wheat", by J. E. Machacek, October 1943 issue of *Scientific Agriculture* (Vol. 24, No. 2), on page 76 the last sentence of the Discussion should read: "It would seem, therefore, that, in weedy fields, common root rot causes even greater damage than in fields comparatively free from weeds, and that, as in Manitoba the percentage of weedy fields is large, the present estimate of loss from common root rot is not too high."